

Supplementary Online Content

Walkey AJ, Weinberg J, Wiener RS, Cooke CR, Lindenauer PK. Association of do-not-resuscitate orders and hospital mortality rates among patients with pneumonia. *JAMA Intern Med.* Published online December 14, 2015.
doi:10.1001/jamainternmed.2015.6324.

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

eMethods. Supplemental Methods

Cohort

Using Agency of Healthcare Research and Quality, Healthcare Cost and Utilization Project, California State Inpatient Database (CA SID),¹⁷ we analyzed a cohort of adults ages 40 and older hospitalized with pneumonia during year 2011. We chose age 40 for our primary analysis as defining a point where patients may be ‘at risk’ for having an early DNR order; in the CA SID, fewer than 1% of patients younger than age 40 had DNR orders. CA SID consists of administrative claims data from all non-Federal hospitalizations in California and, rather uniquely, contains a validated variable that captures DNR orders written during the first 24 hours of hospitalization (87.5% accurate, kappa 0.72 for patients with pneumonia as compared with nurse chart review).^{18, 19} We defined pneumonia hospitalizations using either principal diagnosis claims for pneumonia, or principal diagnosis for acute respiratory failure or septicemia, with a secondary diagnosis of pneumonia that was present on admission (**eTable 1**).^{20, 21} We excluded patients transferred from another hospital, discharged alive within 48 hours,¹⁶ or admitted to a hospital caring for fewer than 25 pneumonia patients in 2011.¹⁶

Early DNR Measures

We characterized both patient-level early DNR status and hospital-level early DNR rates. Early DNR was defined from the CA SID DNR field as a “*directive from a physician in a patient’s current inpatient medical record instructing that the patient is not to be resuscitated in the event of a cardiac or pulmonary arrest.*”¹⁹ Patient early DNR status was categorized as ‘yes’ (DNR ordered within the first 24 hours of hospitalization) or ‘no’ (no DNR order within 24 hours of hospitalization). The hospital DNR rate was defined as the percentage of patients with pneumonia with an early DNR order at each hospital.

Covariates

We risk-adjusted models using patient demographics, comorbidities,²² and acute organ failures present on admission (**eTable 2**).^{23, 24}

Outcomes

We examined associations of patient DNR status and hospital DNR rates with patient in-hospital mortality. Because between-hospital differences in discharge practices may be associated with in-hospital mortality rates,²⁵ we also assessed associations of hospital DNR rates with hospital discharge destinations and length of stay among survivors

Statistical Methods

We presented summary data across hospital quartiles of DNR rate. In order to examine associations between hospital DNR rates and patient mortality accounting for confounding by patient DNR status, analyzed contingency tables for hospital DNR rates and mortality stratified by patient DNR status. We then used SAS GLIMMIX procedure to construct hierarchical logistic regression models with hospital-level random intercepts to examine multivariable-adjusted associations between hospital DNR rates and patient mortality, without accounting for patient DNR status.

We assessed models that included DNR status as a fixed effect without a random DNR slope (ie., without accounting for between-hospital variation in associations between hospital DNR and hospital mortality rates), but model performance [measured by c-statistics and Akaike's Information Criterion (using a Laplace approximation of maximum likelihood)]¹ was inferior to models including DNR as both a fixed and random effect; further, including DNR as a fixed effect and random slope attenuated associations between hospital DNR rates and mortality when compared with models including DNR as fixed effect alone (**eTable 3**). Thus, models adjusting for patient DNR status also included DNR status as a random slope, a technique that allowed the association between patient DNR status and mortality to vary for each hospital²⁻⁵ and attenuated bias that might be introduced in adjustment for DNR status if patients at some hospitals elected DNR status at lower severity of illness than at other hospitals.

Hospitals were ranked according to each hospital's effect estimate as determined by the random effects.⁶ Hospitals with a statistically significantly greater risk-standardized mortality than the average hospital were considered to be significant, low-performing outliers. Hospital risk-standardized mortality rates were calculated from the ratio of hospital-adjusted rates to the average risk-adjusted rate, multiplied by the average

unadjusted hospital rate in California.⁶ We assessed correlation between risk-standardized hospital early DNR rates and hospital outcomes quantitatively using Spearman rank correlation coefficients and visually using penalized b-spline regression.⁷ We tested differences in risk-standardized hospital DNR rates between hospitals ranked in the highest and lowest risk-standardized mortality quartile using Wilcoxon-Mann-Whitney tests. We evaluated the degree of hospital-level variation in early DNR utilization unexplained by measured patient characteristics by calculating intra-class correlation coefficients from hospital-level intercept variance estimates⁸⁻¹⁰ in multivariable-adjusted hierarchical logistic regression models, with early DNR status as the outcome of interest.

We used SAS version 9.3 (Cary, NC) and a two-tailed alpha level of 0.05 for all analyses. All procedures were performed on de-identified data and approved by Boston University Medical Center Institutional Review Board as exempt from review.

Sensitivity Analyses

We performed a sensitivity analysis with a model that adjusted for hospital characteristics (not routinely adjusted for in hospital ranking models) in addition to patient characteristics. We performed a second sensitivity analysis using methods similar to CMS Hospital Compare models, including patients aged 65 years or older with a principal diagnosis of pneumonia, without adjustment for race, income, or acute organ failures.

In order to further inform findings regarding changes in hospital rankings after accounting for DNR status, we assessed the association between hospital risk-standardized DNR rates and non-mortality measures of hospital quality. We linked year 2011 CMS Hospital Compare measures of pneumonia processes of care¹¹ (e.g., receipt of antibiotics within 6 hours, blood cultures prior to antibiotics, smoking cessation counseling, appropriate antibiotics and vaccinations) and patient satisfaction surveys (Hospital Consumer Assessment of Healthcare Providers and Systems, HCAHPS)¹² to CA SID hospital data using an American Hospital Association-Medicare Hospital Number crosswalk. We created composites of hospital quality measures by averaging the percent of patients achieving the quality highest rating (e.g., measure “Always”

performed) for pneumonia processes and HCAHPS responses and assessed Spearman correlation between hospital DNR rates and hospital quality measures.

eTable 1. *International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) Algorithms Used to Define Conditions and Procedures*

| Condition of Procedure | ICD-9-CM Codes |
|--|--|
| Pneumonia | 480-483, 485-487 |
| Acute respiratory failure | 518.81, 518.82, 518.84, 518.85, 786.09, 799.1 |
| Septicemia | 038.x |
| Dementia | 290.0-290.4, 290.8, 290.9, 294.1, 294.8, 294.9 |
| Acute circulatory failure | 458.0, 458.8, 458.9, 796.3, 785.51, 785.59 |
| Acute renal failure | 584 |
| Acute liver failure | 570, 572.2, 573.3 |
| Delirium/acute neurological failure | 293, 348.3, 348.1, 780.0 |
| Acute coagulopathy or thrombocytopenia | 2873, 2874, 2875, 2869, 2866, 2862 |
| Acidosis | 276.2 |
| Septic shock | 785.52 |

eTable 2. Covariates Included in Models/Fixed Effects Output From Hospital Mortality Comparison Models, Primary Analysis Cohort

| Covariate | Without early DNR status | | With early DNR status ^a | |
|----------------------------|--------------------------|---------|------------------------------------|---------|
| | Estimate | P Value | Estimate | P Value |
| Early DNR Status | | | 1.3036 | <.0001 |
| Age, per year | 0.03215 | <.0001 | 0.02282 | <.0001 |
| Race/Ethnicity | | | | |
| White | 0.07517 | .1505 | -0.00321 | .9521 |
| Black | -0.03652 | .5872 | -0.02622 | .7025 |
| Hispanic | 0.02599 | .6492 | 0.01313 | .8221 |
| Asian | 0.02225 | .7242 | 0.03011 | .6410 |
| Other | REF | | REF | |
| Sex, Male | 0.001732 | .9408 | 0.03249 | .1759 |
| Primary Payer | | | | |
| Medicare | 0.01030 | .9140 | 0.004775 | .9612 |
| Medicaid | 0.1498 | .1288 | 0.1459 | .1500 |
| Private Insurance | 0.09293 | .3499 | 0.1184 | .2468 |
| Self-Pay | 0.2541 | .0498 | 0.3009 | .0226 |
| Other | REF | | Reference | |
| Median income for zip code | | | | |
| Quartile 1 | -0.04589 | .2481 | -0.01706 | .6782 |

| | | | | |
|------------------------------------|----------|--------|----------|--------|
| Quartile 2 | -0.05918 | .1203 | -0.03770 | .3375 |
| Quartile 3 | -0.04838 | .1794 | -0.04429 | .2334 |
| Quartile 4 | REF | | REF | |
| Comorbidities | | | | |
| Congestive Heart Failure | 0.2051 | <.0001 | 0.2066 | <.0001 |
| Valvular Heart Disease | -0.05235 | .1803 | -0.03053 | .4449 |
| Pulmonary Circulation Disease | -0.00311 | .9437 | -0.00794 | .8605 |
| Peripheral Vascular Disease | 0.1230 | .0008 | 0.08941 | .0174 |
| Paralysis | 0.01075 | .8222 | -0.05389 | .2713 |
| Other Neurological Disorders | 0.07073 | .0387 | -0.00727 | .8364 |
| Chronic Pulmonary Disease | -0.3453 | <.0001 | -0.3150 | <.0001 |
| Diabetes w/o Chronic Complications | -0.1202 | <.0001 | -0.09505 | .0009 |
| Diabetes w/ Chronic Complications | -0.1610 | <.0001 | -0.1368 | .0012 |
| Hypothyroidism | -0.06516 | .0364 | -0.07468 | .0197 |
| Renal failure | 0.3960 | <.0001 | 0.4193 | <.0001 |

| | | | | |
|-------------------------------------|---------|--------|---------|--------|
| Liver disease | 0.3453 | <.0001 | 0.3215 | <.0001 |
| Peptic ulcer Disease w/ Bleeding | 0.1873 | .6389 | 0.2117 | .6134 |
| AIDS | 0.1288 | .4830 | 0.03632 | .8482 |
| Lymphoma | 0.5961 | <.0001 | 0.5951 | <.0001 |
| Metastatic Cancer | 1.4188 | <.0001 | 1.2814 | <.0001 |
| Solid Tumor w/out Metastasis | 0.7505 | <.0001 | 0.7005 | <.0001 |
| Collagen Vascular Disease | 0.1141 | .0471 | 0.1100 | .0627 |
| Coagulopathy | 1.0234 | <.0001 | 1.1220 | <.0001 |
| Obesity | -0.2527 | <.0001 | -0.2063 | <.0001 |
| Weight Loss/Malnutrition | 0.2366 | <.0001 | 0.2191 | <.0001 |
| Fluid and Electrolyte Disorders | 0.1700 | <.0001 | 0.1823 | <.0001 |
| Chronic Blood Loss Anemia | -0.1314 | .1705 | -0.1481 | .1303 |
| Deficiency Anemias | -0.3055 | <.0001 | -0.2985 | <.0001 |
| Alcohol Abuse | 0.1152 | .0506 | 0.1153 | .0569 |
| Drug Abuse | -0.3719 | <.0001 | -0.3834 | <.0001 |
| Psychoses | -0.2786 | <.0001 | -0.2602 | <.0001 |
| Depression | -0.1281 | .0015 | -0.1446 | .0005 |

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|--|---------|--------|----------|--------|
| Hypertension | -0.2407 | <.0001 | -0.2211 | <.0001 |
| Dementia | 0.06883 | .0337 | -0.06185 | .0647 |
| Acute Organ Failure | | | | |
| Renal Failure | 0.4635 | <.0001 | 0.4483 | <.0001 |
| Hematologic Failure | -0.6339 | <.0001 | -0.7194 | <.0001 |
| Acidosis | 0.4006 | <.0001 | 0.3890 | <.0001 |
| Neurological Failure | 0.2611 | <.0001 | 0.2492 | <.0001 |
| Liver Failure | 0.7971 | <.0001 | 0.7858 | <.0001 |
| Respiratory Failure | 1.1092 | <.0001 | 1.0969 | <.0001 |
| Shock | 1.1057 | <.0001 | 1.1355 | <.0001 |
| ^a DNR also included as a random slope | | | | |

eTable 3. Model Performance Changes Based on Method of Inclusion of Early Do-Not-Resuscitate Status

| Model DNR status | c-statistic (95% CI) | Akaike's Information Criterion^a | Correlation^b between Hospital DNR rate and Hospital Mortality rate |
|---|-----------------------------|---|--|
| No DNR | 0.808 (0.804-0.812) | 55167.71 | 0.242 <i>P</i> < .001 |
| DNR as fixed effect only | 0.829 (0.825-0.833) | 52848.13 | -0.175 <i>P</i> = .002 |
| DNR as fixed effect and random slope^c | 0.833 (0.829-0.837) | 52725.70 | -0.149 <i>P</i> = .01 |

^a Lower Akaike's Information Criterion indicates improved model performance; model uses method of Laplace to obtain maximum likelihood estimates.
^bSpearman rank correlation coefficient Abbreviations: DNR: early do-not-resuscitate order, written within 24 hours of hospitalization
All models include hospital random intercepts and are adjusted for 42 covariates including patient demographics, comorbid conditions and acute organ failures.
The variation in hospital-specific DNR coefficient intercepts ranged from 2.8% to 30% mortality rates
Other model variables are shown in eTable 4

eTable 4. Distribution of Comorbid Conditions, Acute Organ Failures, and Hospital Characteristics Across Quartiles of Hospital Early Do-Not-Resuscitate Order Rate

| Hospital Quartile of DNR rate | | | | | |
|---|---|--|--|---|----------------|
| Characteristic, N (%) unless otherwise noted | Quartile 1 < 8.9% N=22602 | Quartile2 8.9-15.8% N=22456 | Quartile 3 15.9-22.3% N=22718 | Quartile 4 >22.3% N=22868 | P Value |
| Comorbidities | | | | | |
| Number of comorbidities (mean ± sd) | 4.43 ± 2.0 | 4.36 ± 2.0 | 4.38 ± 2.0 | 4.37 ± 2.0 | .006 |
| Congestive Heart Failure | 7579 (33.5) | 7477 (33.3) | 7241 (31.9) | 7660 (33.5) | .28 |
| Valvular Heart Disease | 1625 (7.2) | 1795 (8.0) | 2145 (9.4) | 2746 (12.0) | <.001 |
| Pulmonary Circulation Disease | 1295 (5.7) | 1454 (6.5) | 1556 (6.9) | 1873 (8.2) | <.001 |
| Peripheral Vascular Disease | 1697 (7.5) | 1774 (7.9) | 2660 (11.7) | 3248 (14.2) | <.001 |
| Hypertension | 15196 (67.2) | 14835 (66.1) | 15103 (66.5) | 15122 (66.1) | .04 |
| Paralysis | 1504 (6.7) | 1274 (5.7) | 1155 (5.1) | 1154 (5.1) | <.001 |
| Other Neurological Disorders | 3303 (14.6) | 3112 (13.9) | 2927 (12.9) | 2593 (11.3) | <.001 |
| Chronic Pulmonary Disease | 10679 (47.3) | 10460 (46.6) | 10416 (45.9) | 10507 (46.0) | .002 |
| Diabetes w/o Chronic Complications | 6878 (30.4) | 6315 (28.2) | 5597 (24.7) | 4120 (18.0) | <.001 |
| Diabetes w/ Chronic Complications | 2055 (9.1) | 1938 (8.6) | 2333 (10.3) | 3178 (13.9) | <.001 |
| Hypothyroidism | 3277 (14.5) | 3518 (15.7) | 4010 (17.7) | 3941 (17.2) | <.001 |
| Renal failure | 1955 (8.7) | 1685 (7.5) | 1476 (6.5) | 1200 (5.3) | <.001 |
| Liver disease | 1203 (5.3) | 1027 (4.6) | 1177 (5.2) | 997 (4.4) | <.001 |
| Peptic ulcer Disease w/ Bleeding | 21 (0.1) | 26 (0.1) | 13 (0.06) | <10 (<0.06) | <.01 |
| AIDS | 193 (0.9) | 108 (0.5) | 97 (0.4) | 77 (0.3) | 0.001 |
| Lymphoma | 392 (1.7) | 401 (1.8) | 519 (2.3) | 532 (2.3) | <.001 |
| Metastatic Cancer | 915 (4.1) | 974 (4.3) | 1083 (4.8) | 1174 (5.1) | <.001 |

| | | | | | |
|---|-------------|--------------|--------------|--------------|-------|
| Solid Tumor w/out Metastasis | 905 (4.0) | 876 (3.9) | 943 (4.2) | 966 (4.2) | .12 |
| Collagen Vascular Disease | 792 (3.5) | 916 (4.1) | 964 (4.2) | 1188 (5.2) | <.001 |
| Coagulopathy | 2343 (10.4) | 2441 (10.9) | 2208 (9.7) | 2342 (10.2) | .09 |
| Obesity | 2523 (11.2) | 2311 (10.3) | 2549 (11.2) | 2701 (11.8) | .002 |
| Weight Loss/Malnutrition | 3783 (16.7) | 3569 (15.9) | 3714 (16.4) | 3790 (16.6) | .98 |
| Fluid and Electrolyte Disorders | 11100(49.1) | 11118 (49.5) | 11004 (48.4) | 10765 (47.1) | <.001 |
| Chronic Blood Loss Anemia | 291 (1.3) | 312 (1.4) | 256 (1.1) | 191 (0.9) | <.001 |
| Deficiency Anemias | 9229 (40.8) | 9016 (40.2) | 8861 (39.0) | 8303 (36.3) | <.001 |
| Alcohol Abuse | 1076 (4.8) | 893 (4.0) | 922 (4.1) | 976 (4.3) | .02 |
| Drug Abuse | 848 (3.8) | 612 (2.7) | 778 (3.4) | 737 (3.2) | .09 |
| Psychoses | 1672 (7.4) | 1562 (7.0) | 1741 (7.7) | 1902 (8.3) | <.001 |
| Depression | 1993 (8.8) | 2379 (10.6) | 2623 (11.6) | 2532 (11.1) | <.001 |
| Dementia | 3774 (16.7) | 3778 (16.8) | 3376 (14.9) | 3366 (14.7) | <.001 |
| Acute Organ Failures | | | | | |
| Number of acute organ Failures, mean (SD) | 0.98 (1.2) | 0.96 (1.2) | 0.91 (1.1) | 0.85 (1.0) | <.001 |
| Shock | 2947 (13.0) | 2762 (12.3) | 2657 (11.7) | 2153 (9.4) | .001 |
| Respiratory Failure | 6772 (30.0) | 7107 (31.7) | 7030 (30.9) | 6535 (28.9) | <.001 |
| Renal Failure | 5363 (23.7) | 5112 (22.8) | 5056 (22.3) | 4671 (20.4) | <.001 |
| Neurological Failure | 2575 (11.4) | 2235 (10.0) | 1762 (7.8) | 1718 (7.5) | <.001 |
| Hematologic Failure | 1956 (8.7) | 2056 (9.2) | 1848 (8.1) | 2027 (8.9) | .65 |
| Liver Failure | 447 (2.0) | 354 (1.6) | 381 (1.7) | 286 (1.3) | <.001 |
| Acidosis | 2028 (9.0) | 1986 (8.8) | 1826 (8.0) | 2058 (9.0) | .39 |
| Hospital Characteristics^a | | | | | |
| Bed Size ^b | | | | | <.001 |

| | | | | | |
|-------------------------|--------------|--------------|--------------|--------------|-------|
| Small | 1062 (4.9) | 1254 (5.7) | 786 (3.6) | 1506 (6.9) | |
| Medium | 6883 (31.9) | 4300 (20.0) | 3411 (15.7) | 5670 (25.9) | |
| Large | 13658 (63.2) | 16318 (74.6) | 17541 (80.7) | 14734 (67.3) | |
| Teaching hospital | 3265 (14.5) | 3389 (15.1) | 1882 (8.3) | 1664 (7.3) | <.001 |
| Urban Location | 20476 (90.6) | 20883 (93.0) | 19697 (86.7) | 20452 (89.4) | <.001 |
| Hospital control | | | | | <.001 |
| Government | 2923 (13.1) | 3373 (15.0) | 2853 (12.6) | 2285 (10.0) | |
| Private, investor-owned | 7269 (32.6) | 7527 (33.5) | 2733 (12.0) | 284 (1.2) | |
| Private, non-profit | 12122 (54.3) | 11556 (51.5) | 17132 (75.4) | 20299 (88.8) | |

DNR: Do-Not-Resuscitate order within first 24 hours of hospitalization

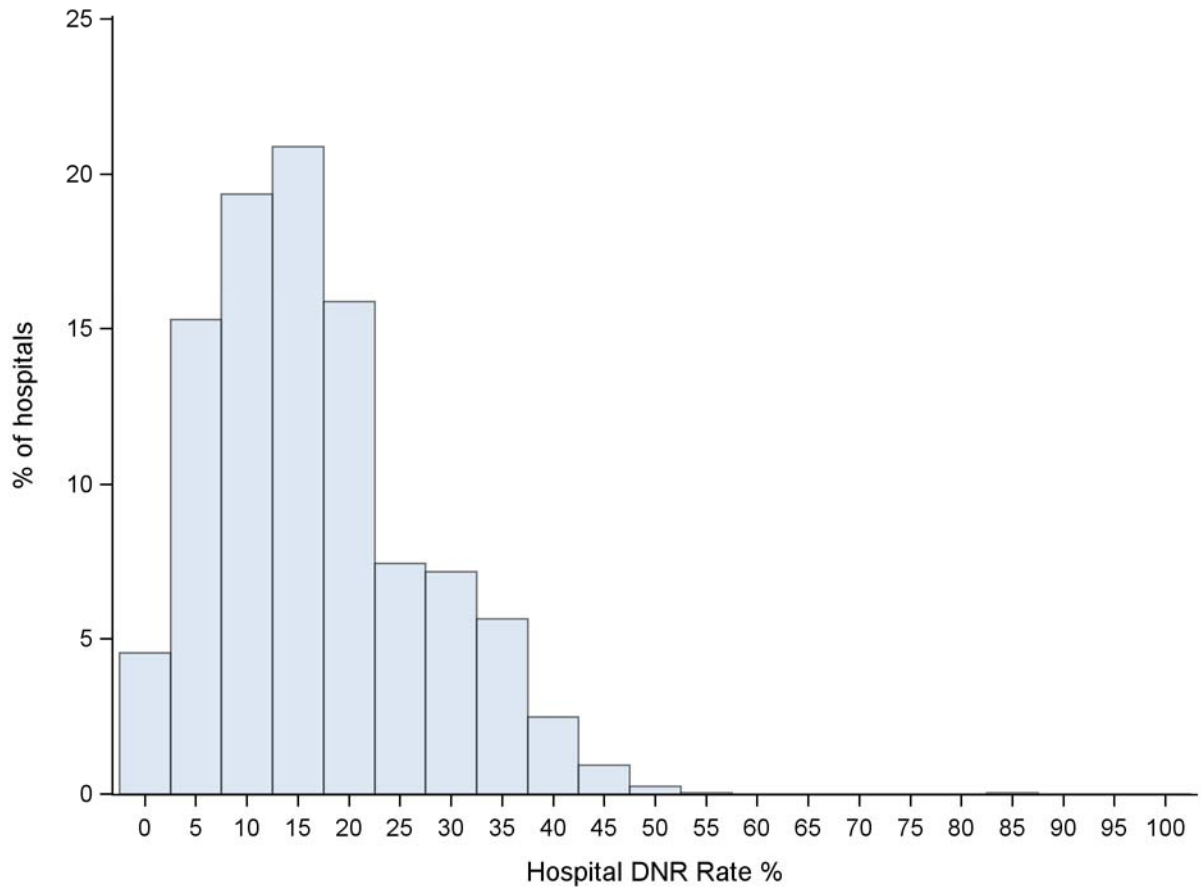
^a Included as covariates in sensitivity analysis

^b Hospital bedsize determined by bed number, urban/rural status, and teaching status as per HCUP algorithms (eg., small: 1-49 for rural, 1-99 for urban non-teaching, and 1-299 beds for urban teaching).

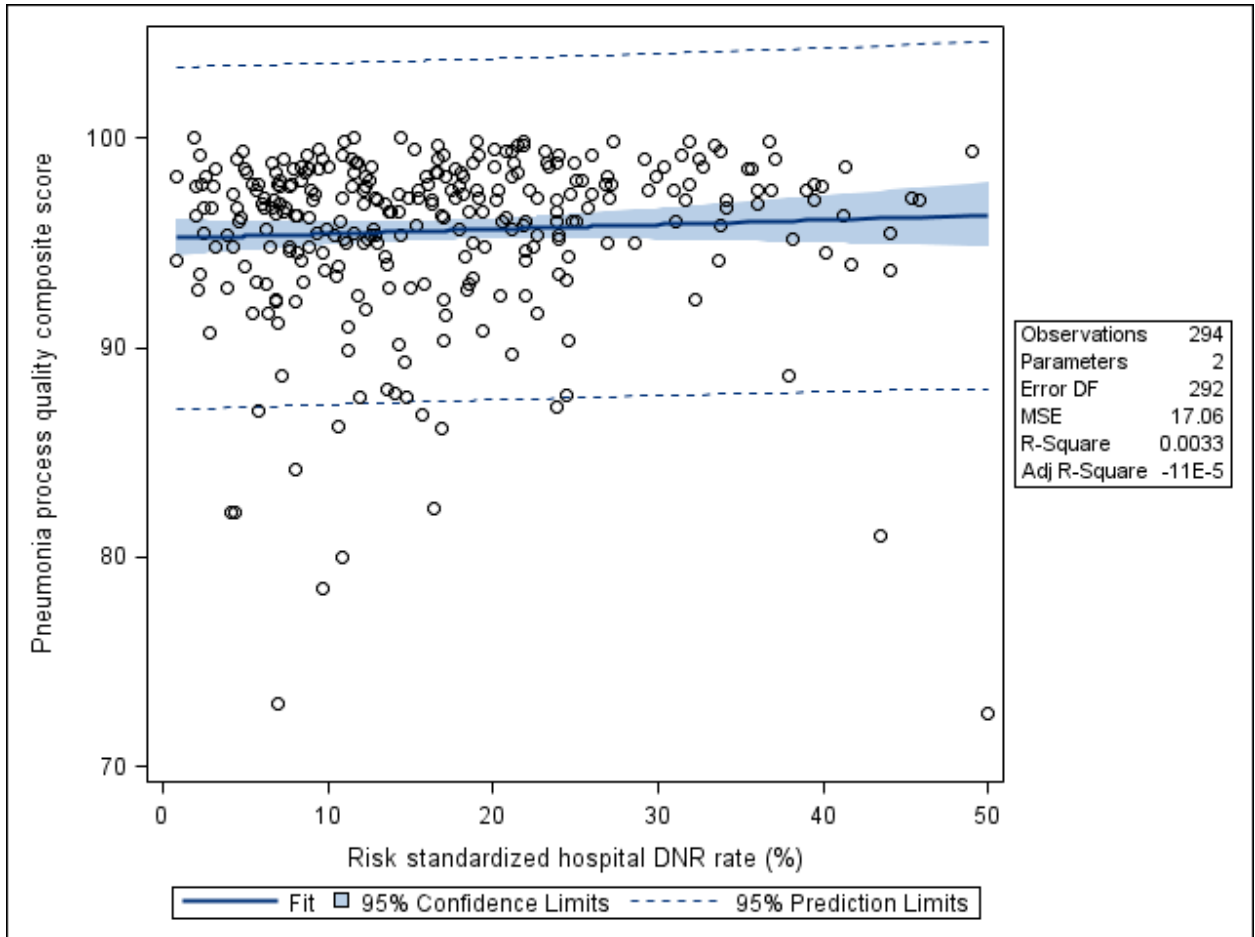
eTable 5. Results of Sensitivity Analyses

| Analysis | Primary Analysis | Models including hospital characteristics | Models approximating CMS Hospital Compare analyses |
|--|-------------------------|--|---|
| Mortality: Highest DNR quartile vs Lowest, Without DNR, odds ratio (95% CI) | 1.17 (1.04-1.32) | 1.20 (1.06-1.37) | 1.28 (1.08-1.52) |
| Mortality: Highest DNR quartile vs Lowest, With DNR, odds ratio (95% CI) | 0.79 (0.70-0.89) | 0.82 (0.72-0.94) | 0.76 (0.64-0.91) |
| Outlier hospitals remaining as significant outliers after adjusting for DNR | 14 of 27 (52%) | 11 of 24 (46%) | 5 of 8 (63%) |

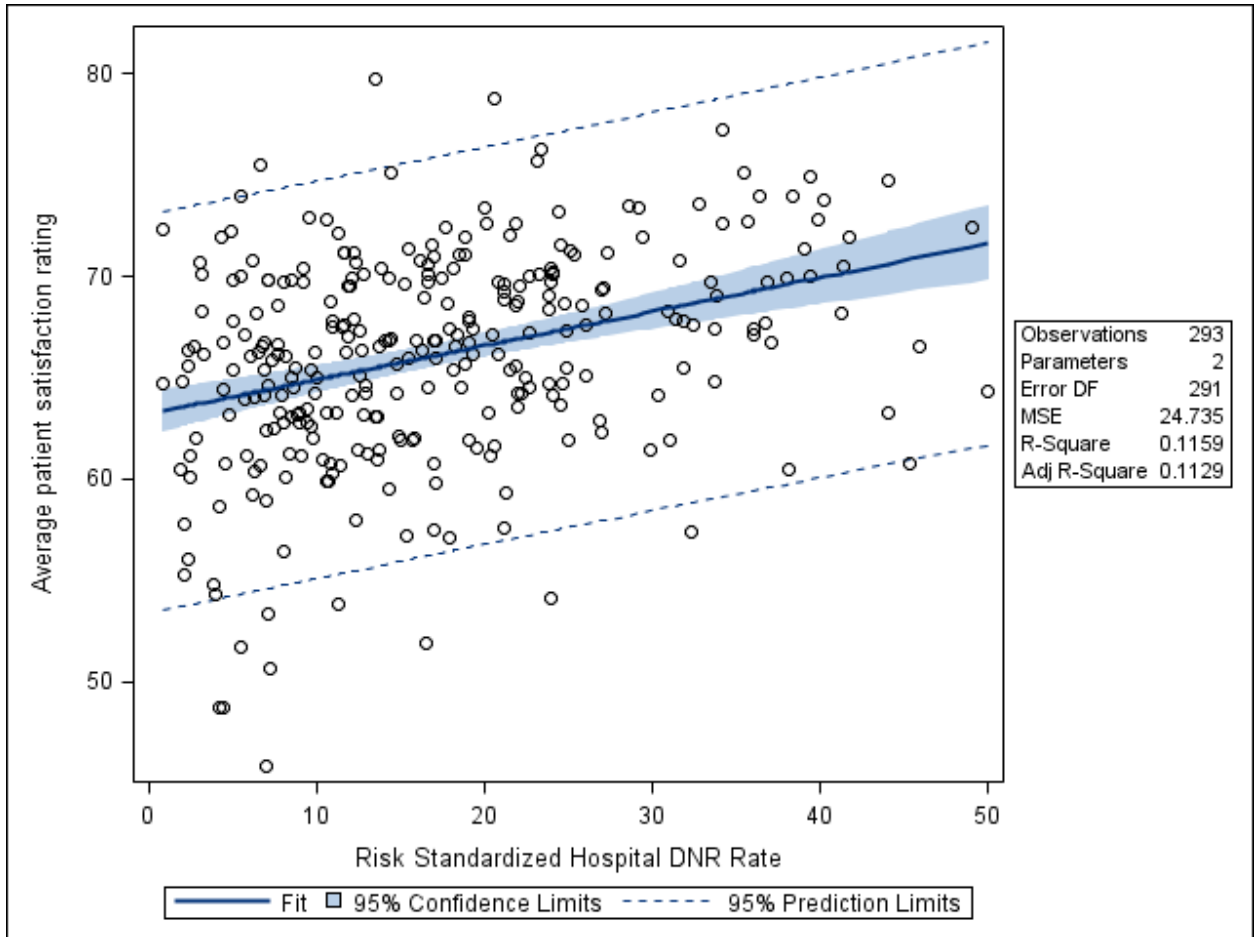
eFigure 1. Distribution of Hospital Do-Not-Resuscitate Rates



eFigure 2. Association Between Hospital DNR Rate and Composite Quality Measure of Hospital Processes of Care for Pneumonia



eFigure 3. Association Between Hospital DNR Rate and Composite Measure Patient Satisfaction



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