

Supplementary Online Content

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

eFigure: Illustration of Continuity of Care Score and Usual Provider Continuity Score

| | Physician A | Physician B | Physician C | Physician D | Physician E | Physician F | Physician G | Physician H | Continuity of Care Score | Usual Provider Continuity Score |
|-----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------------------|---------------------------------|
| Patient A | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 1.000 |
| Patient B | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.750 | 0.875 |
| Patient C | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.571 | 0.750 |
| Patient D | 6 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0.536 | 0.750 |
| Patient E | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.464 | 0.625 |
| Patient F | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0.429 | 0.625 |
| Patient G | 5 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0.393 | 0.625 |
| Patient H | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0.357 | 0.500 |
| Patient I | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0.321 | 0.500 |
| Patient J | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0.250 | 0.500 |
| Patient K | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0.214 | 0.500 |
| Patient L | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0.143 | 0.375 |
| Patient M | 3 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0.107 | 0.375 |
| Patient N | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0.036 | 0.250 |
| Patient O | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.000 | 0.125 |

NOTE: Illustration of how the continuity of care score and usual provider continuity score operate. Numbers denote hypothetical visit patterns, where each patient's number of visits with each physician is scored against a total number of visits held constant at 8 for all patients. Shading represents hypothetical cutpoints for lowest (red), medium (orange), and high (yellow) levels of continuity for the continuity of care score and usual provider continuity score.

E-Methods

Sensitivity Analyses

Sensitivity analyses examined whether the results were different if the models were stratified by baseline risk based on quintiles of total visits in the previous year to assess the sensitivity of the main effects to the assumption of a common baseline hazard; for death as the primary outcome to test for “healthy survivor” effects; for all patients with 1 or more visits; for continuity scores lagged 1, 3, 6, and 12 months to determine whether earlier levels of continuity in a patient’s visit pattern may be related to risk of preventable hospitalization, rather than levels of continuity immediately preceding the event; and for subsets of chronically ill patients who had a hospitalization specific to their condition since sicker patients are more likely to incur a preventable hospitalization. For the chronically ill patients, we conducted separate analyses for those who were hospitalized for or ever had CHF (n = 1,017,761), chronic obstructive pulmonary disease (COPD) (n = 935,877), or diabetes (n = 1,211,680), as identified using 2008 chronic condition flags from the Chronic Condition Warehouse.

In sensitivity analyses, the models were robust to stratifying by total visits in the year prior to the observation period. The models ignoring preventable hospitalization and using death as the event showed a null relationship for both continuity metrics, so the effects we observed in the preventable hospitalization analysis presumably could not be explained by patients with high continuity who died and, hence, were censored. When all patients with 1 or more visits were included in unadjusted models, the rate of preventable hospitalization was the same or lower as patients with 4 or more visits for the continuity of care score (HR 0.98, 95% CI 0.98—0.98) and the usual provider continuity score (HR 0.96, 95% 0.96—0.96). Lagged analyses of up to 12 months showed almost the same results as their non-lagged counterparts (eTables 1 and 2). For patients with CHF or diabetes, higher continuity was associated with a lower and statistically significant risk of preventable hospitalization for their condition for both continuity metrics (eTables 3-5). However, risk of preventable hospitalization slightly increased with higher continuity according to both the continuity of care score and usual provider continuity score adjusted models for patients with COPD.

eTable 1: Continuity of Care Score Lagged Analyses.

| | No Lag | 1 Month | 3 Months | 6 Months | 12 Months |
|--|------------------|------------------|------------------|------------------|------------------|
| Bivariate model | | | | | |
| Continuity | 0.98 (0.98—0.98) | 0.99 (0.98—0.98) | 0.98 (0.98—0.98) | 0.98 (0.98—0.98) | 0.98 (0.98—0.98) |
| Multivariate model | | | | | |
| Continuity | 0.98 (0.98—0.99) | 0.99 (0.98—0.99) | 0.98 (0.98—0.99) | 0.99 (0.98—0.99) | 0.99 (0.98—0.99) |
| Female | 1.17 (1.16—1.18) | 1.18 (1.17—1.18) | 1.18 (1.17—1.18) | 1.17 (1.16—1.18) | 1.15 (1.14—1.16) |
| Age | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) |
| Race and ethnicity | | | | | |
| White non-Hispanic | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Black | 1.07 (1.06—1.08) | 1.09 (1.07—1.10) | 1.09 (1.07—1.10) | 1.09 (1.08—1.11) | 1.10 (1.08—1.11) |
| Hispanic | 1.07 (1.05—1.09) | 1.01 (1.00—1.03) | 1.01 (0.99—1.02) | 1.00 (0.98—1.02) | 0.97 (0.95—0.99) |
| Asian | 0.84 (0.82—0.87) | 0.76 (0.74—0.78) | 0.75 (0.72—0.77) | 0.73 (0.71—0.75) | 0.69 (0.66—0.71) |
| Other | 1.01 (0.98—1.05) | 0.98 (0.95—1.01) | 0.98 (0.95—1.02) | 0.99 (0.96—1.03) | 1.00 (0.96—1.04) |
| Medicaid dual eligible | 1.06 (1.05—1.07) | 1.07 (1.06—1.08) | 1.07 (1.06—1.08) | 1.07 (1.06—1.08) | 1.10 (1.09—1.11) |
| Hierarchical condition categories score | | | | | |
| Low | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mild | 1.41 (1.39—1.43) | 1.44 (1.42—1.46) | 1.47 (1.44—1.49) | 1.50 (1.48—1.52) | 1.57 (1.54—1.60) |
| Moderate | 1.77 (1.75—1.80) | 1.82 (1.80—1.85) | 1.87 (1.84—1.90) | 1.95 (1.92—1.98) | 2.15 (2.11—2.19) |
| Severe | 1.84 (1.81—1.86) | 1.91 (1.88—1.93) | 1.98 (1.95—2.01) | 2.11 (2.08—2.14) | 2.51 (2.47—2.56) |
| Total visits in prior year | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.02 (1.01—1.02) |
| Total preventable hospitalizations in prior year | 1.17 (1.17—1.18) | 1.20 (1.19—1.21) | 1.22 (1.21—1.22) | 1.24 (1.23—1.24) | 1.28 (1.27—1.29) |

NOTE: Lagged analyses restricted to patients with more months of observation than their respective lag times. Hazard ratios (95% CI) show rate of preventable hospitalization between 2008 and 2010 for Medicare patients older than 65 years of age with at least 4 visits in 2008. Bivariate model is the relationship between preventable hospitalization and continuity; multivariate model is the relationship between preventable hospitalization and continuity, controlling for all covariates. For every 0.1 increase in the continuity of care score or usual provider continuity score, results show the decrease in rate of preventable hospitalization. Female is relative to male; Medicaid dual eligible is relative to Medicare-only coverage. Age is in units of years; total visits in prior year are in units of ambulatory visits; and total preventable hospitalizations in prior year are in units of hospitalizations. Total visits and preventable hospitalizations in prior year refer to utilization that occurred during the 365 days before the start of a patient's observation period. No Hospital Referral Region fixed effects included in lagged models.

eTable 2: Usual Provider Continuity Score Lagged Analyses.

| | No Lag | 1 Month | 3 Months | 6 Months | 12 Months |
|--|------------------|------------------|------------------|------------------|------------------|
| Bivariate model | | | | | |
| Continuity | 0.98 (0.97—0.98) | 0.98 (0.97—0.98) | 0.97 (0.97—0.98) | 0.97 (0.97—0.98) | 0.97 (0.97—0.98) |
| Multivariate model | | | | | |
| Continuity | 0.98 (0.98—0.98) | 0.98 (0.98—0.98) | 0.98 (0.98—0.98) | 0.98 (0.98—0.99) | 0.99 (0.99—0.99) |
| Female | 1.17 (1.17—1.18) | 1.18 (1.17—1.18) | 1.18 (1.17—1.18) | 1.17 (1.16—1.18) | 1.15 (1.14—1.16) |
| Age | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) | 1.00 (1.00—1.00) |
| Race and ethnicity | | | | | |
| White non-Hispanic | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Black | 1.07 (1.06—1.09) | 1.09 (1.07—1.10) | 1.09 (1.07—1.10) | 1.09 (1.08—1.11) | 1.10 (1.08—1.11) |
| Hispanic | 1.07 (1.05—1.09) | 1.01 (1.00—1.03) | 1.00 (0.99—1.02) | 1.00 (0.98—1.02) | 0.97 (0.95—0.99) |
| Asian | 0.84 (0.82—0.87) | 0.76 (0.74—0.78) | 0.75 (0.72—0.77) | 0.73 (0.71—0.75) | 0.69 (0.66—0.71) |
| Other | 1.02 (0.98—1.05) | 0.98 (0.95—1.01) | 0.99 (0.95—1.02) | 0.99 (0.96—1.03) | 1.00 (0.96—1.04) |
| Medicaid dual eligible | 1.06 (1.05—1.07) | 1.07 (1.06—1.08) | 1.07 (1.06—1.08) | 1.07 (1.06—1.08) | 1.10 (1.09—1.11) |
| Hierarchical condition categories score | | | | | |
| Low | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mild | 1.41 (1.40—1.43) | 1.44 (1.42—1.46) | 1.47 (1.44—1.49) | 1.50 (1.48—1.52) | 1.57 (1.54—1.60) |
| Moderate | 1.77 (1.75—1.80) | 1.82 (1.80—1.85) | 1.87 (1.84—1.90) | 1.95 (1.92—1.98) | 2.15 (2.11—2.19) |
| Severe | 1.83 (1.81—1.86) | 1.90 (1.88—1.93) | 1.98 (1.95—2.01) | 2.11 (2.08—2.14) | 2.51 (2.46—2.56) |
| Total visits in prior year | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.01 (1.01—1.01) | 1.02 (1.01—1.02) |
| Total preventable hospitalizations in prior year | 1.17 (1.17—1.18) | 1.20 (1.19—1.21) | 1.22 (1.21—1.22) | 1.24 (1.23—1.24) | 1.28 (1.27—1.29) |

NOTE: Lagged analyses restricted to patients with more months of observation than their respective lag times. Hazard ratios (95% CI) show rate of preventable hospitalization between 2008 and 2010 for Medicare patients older than 65 years of age with at least 4 visits in 2008. Bivariate model is the relationship between preventable hospitalization and continuity; multivariate model is the relationship between preventable hospitalization and continuity, controlling for all covariates. For every 0.1 increase in the continuity of care score or usual provider continuity score, results show the decrease in rate of preventable hospitalization. Female is relative to male; Medicaid dual eligible is relative to Medicare-only coverage. Age is in units of years; total visits in prior year are in units of ambulatory visits; and total preventable hospitalizations in prior year are in units of hospitalizations. Total visits and preventable hospitalizations in prior year refer to utilization that occurred during the 365 days before the start of a patient's observation period. No Hospital Referral Region fixed effects included in models.

eTable 3: Chronically Ill Patient Baseline Demographic Characteristics.

| | Preventable Hospitalization | No Preventable Hospitalization |
|---|-----------------------------|--------------------------------|
| CHF | | |
| N (%) | 103,758 (10.2) | 914,003 (89.8) |
| Female, % | 55.6 | 57.5 |
| Age, mean yrs. (SD) | 81.0 (7.7) | 80.4 (7.5) |
| Race and ethnicity, % | | |
| White non-Hispanic | 85.3 | 83.5 |
| Black | 8.3 | 7.7 |
| Hispanic | 4.4 | 5.6 |
| Asian | 1.2 | 2.3 |
| Other | 0.9 | 1.0 |
| Medicaid dual eligible, % | 22.1 | 21.0 |
| Hierarchical condition categories score, % | | |
| Low | 12.9 | 26.5 |
| Mild | 19.4 | 25.6 |
| Moderate | 27.3 | 24.7 |
| Severe | 40.5 | 23.2 |
| Total visits in prior year, mean (SD) | 13.6 (8.8) | 12.0 (7.9) |
| Total preventable hospitalizations in prior year, mean (SD) | 0.36 (0.8) | 0.12 (0.4) |
| COPD | | |
| N (%) | 60,323 (6.5) | 875,554 (93.6) |
| Female, % | 56.7 | 56.9 |
| Age, mean yrs. (SD) | 77.7 | 78.5 |
| Race and ethnicity, % | | |
| White non-Hispanic | 88.9 | 86.1 |
| Black | 5.7 | 5.9 |
| Hispanic | 3.5 | 5.0 |
| Asian | 1.0 | 2.1 |
| Other | 0.9 | 1.0 |
| Medicaid dual eligible, % | 26.2 | 19.9 |
| Hierarchical condition categories score, % | | |
| Low | 13.1 | 26.1 |
| Mild | 20.9 | 25.1 |
| Moderate | 27.9 | 24.8 |
| Severe | 38.1 | 24.1 |
| Total visits in prior year, mean (SD) | 12.8 (8.4) | 11.8 (7.8) |
| Total preventable hospitalizations in prior year, mean (SD) | 0.45 (0.9) | 0.13 (0.4) |

eTable 3: Chronically Ill Patient Baseline Demographic Characteristics, continued.

| | Preventable Hospitalization | No Preventable Hospitalization |
|---|------------------------------------|---------------------------------------|
| Diabetes | | |
| N (%) | 27,620 (2.3) | 1,184,060 (97.7) |
| Female, % | 53.7 | 56.1 |
| Age, mean yrs. (SD) | 76.7 (7.3) | 76.6 (7.2) |
| Race and ethnicity, % | | |
| White non-Hispanic | 70.9 | 79.3 |
| Black | 16.3 | 9.2 |
| Hispanic | 9.0 | 7.1 |
| Asian | 2.1 | 3.1 |
| Other | 1.6 | 1.3 |
| Medicaid dual eligible, % | 31.2 | 19.6 |
| Hierarchical condition categories score, % | | |
| Low | 9.3 | 25.6 |
| Mild | 15.5 | 25.0 |
| Moderate | 25.5 | 25.0 |
| Severe | 49.8 | 24.4 |
| Total visits in prior year, mean (SD) | 13.0 (8.8) | 11.0 (7.4) |
| Total preventable hospitalizations in prior year, mean (SD) | 0.28 (0.7) | 0.09 (0.4) |

NOTE: Chronically ill Medicare patients older than 65 years of age with at least 4 ambulatory visits during up to 2 years of follow up between 2008 and 2010. Total visits and preventable hospitalizations in prior year refer to utilization that occurred during the 365 days before the start of a patient's observation period in 2008. Patients with congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), or diabetes could have more than 1 chronic illness.

eTable 4: Continuity of Care Score and Risk of Preventable Hospitalization for the Chronically Ill.

| | CHF | COPD | Diabetes |
|--|------------------|------------------|------------------|
| Bivariate model | | | |
| Continuity | 0.97 (0.97—0.97) | 1.01 (1.00—1.01) | 0.96 (0.96—0.97) |
| Multivariate model | | | |
| Continuity | 0.98 (0.98—0.98) | 1.02 (1.01—1.02) | 0.97 (0.97—0.98) |
| Female | 1.08 (1.06—1.09) | 1.22 (1.20—1.24) | 1.07 (1.05—1.10) |
| Age | 1.00 (1.00—1.00) | 0.95 (0.95—0.95) | 0.95 (0.95—0.96) |
| Race and ethnicity | | | |
| White non-Hispanic | 1.0 | 1.0 | 1.0 |
| Black | 1.14 (1.12—1.17) | 0.81 (0.79—0.84) | 1.81 (1.75—1.88) |
| Hispanic | 1.13 (1.09—1.17) | 0.81 (0.77—0.85) | 1.57 (1.50—1.66) |
| Asian | 0.87 (0.82—0.93) | 0.75 (0.69—0.82) | 1.09 (1.00—1.19) |
| Other | 1.01 (0.94—1.08) | 0.83 (0.76—0.90) | 1.35 (1.23—1.49) |
| Medicaid dual eligible | 0.88 (0.87—0.90) | 1.04 (1.02—1.06) | 1.08 (1.05—1.12) |
| Hierarchical condition categories score | | | |
| Low | 1.0 | 1.0 | 1.0 |
| Mild | 1.22 (1.19—1.25) | 1.47 (1.43—1.52) | 1.47 (1.40—1.54) |
| Moderate | 1.37 (1.34—1.40) | 1.56 (1.51—1.60) | 1.89 (1.80—1.98) |
| Severe | 1.29 (1.26—1.31) | 1.18 (1.15—1.22) | 1.83 (1.74—1.92) |
| Total visits in prior year | 1.01 (1.01—1.01) | 1.00 (1.00—1.01) | 1.01 (1.00—1.01) |
| Total preventable hospitalizations in prior year | 1.17 (1.17—1.18) | 1.26 (1.25—1.27) | 1.06 (1.05—1.08) |

NOTE: Hazard ratios (95% CI) show rate of preventable hospitalization between 2008 and 2010 for chronically ill Medicare patients older than 65 years of age with at least 4 visits in 2008. Bivariate model is the relationship between preventable hospitalization and continuity; multivariate model is the relationship between preventable hospitalization and continuity, controlling for all covariates. For every 0.1 increase in the continuity of care score or usual provider continuity score, results show the decrease in rate of preventable hospitalization. Female is relative to male; Medicaid dual eligible is relative to Medicare-only coverage. Age is in units of years; total visits in prior year are in units of ambulatory visits; and total preventable hospitalizations in prior year are in units of hospitalizations. Total visits and preventable hospitalizations in prior year refer to utilization that occurred during the 365 days before the start of a patient's observation period. Multivariate model includes Hospital Referral Region fixed effects. CHF denotes congestive heart failure; COPD denotes chronic obstructive pulmonary disease. Patients could have more than one chronic illness.

eTable 5: Usual Provider Continuity Score and Risk of Preventable Hospitalization for the Chronically Ill.

| | CHF | COPD | Diabetes |
|--|------------------|------------------|------------------|
| Bivariate model | | | |
| Continuity | 0.96 (0.96—0.96) | 1.00 (1.00—1.00) | 0.95 (0.94—0.95) |
| Multivariate model | | | |
| Continuity | 0.97 (0.97—0.97) | 1.01 (1.01—1.02) | 0.96 (0.96—0.97) |
| Female | 1.08 (1.07—1.09) | 1.22 (1.20—1.24) | 1.07 (1.05—1.10) |
| Age | 1.00 (1.00—1.00) | 0.95 (0.95—0.95) | 0.95 (0.95—0.96) |
| Race and ethnicity | | | |
| White non-Hispanic | 1.0 | 1.0 | 1.0 |
| Black | 1.15 (1.12—1.17) | 0.81 (0.79—0.84) | 1.81 (1.75—1.88) |
| Hispanic | 1.14 (1.10—1.18) | 0.81 (0.77—0.85) | 1.58 (1.50—1.66) |
| Asian | 0.88 (0.83—0.93) | 0.75 (0.69—0.82) | 1.10 (1.01—1.20) |
| Other | 1.01 (0.94—1.08) | 0.83 (0.76—0.90) | 1.35 (1.23—1.49) |
| Medicaid dual eligible | 0.89 (0.87—0.90) | 1.04 (1.02—1.06) | 1.09 (1.06—1.12) |
| Hierarchical condition categories score | | | |
| Low | 1.0 | 1.0 | 1.0 |
| Mild | 1.22 (1.19—1.24) | 1.48 (1.43—1.52) | 1.46 (1.39—1.54) |
| Moderate | 1.37 (1.34—1.40) | 1.56 (1.51—1.60) | 1.88 (1.79—1.97) |
| Severe | 1.28 (1.26—1.31) | 1.18 (1.15—1.21) | 1.82 (1.74—1.91) |
| Total visits in prior year | 1.01 (1.01—1.01) | 1.00 (1.00—1.01) | 1.00 (1.00—1.01) |
| Total preventable hospitalizations in prior year | 1.17 (1.17—1.18) | 1.26 (1.25—1.27) | 1.06 (1.05—1.08) |

NOTE: Hazard ratios (95% CI) show rate of preventable hospitalization between 2008 and 2010 for chronically ill Medicare patients older than 65 years of age with at least 4 visits in 2008. Bivariate model is the relationship between preventable hospitalization and continuity; multivariate model is the relationship between preventable hospitalization and continuity, controlling for all covariates. For every 0.1 increase in the continuity of care score or usual provider continuity score, results show the decrease in rate of preventable hospitalization. Female is relative to male; Medicaid dual eligible is relative to Medicare-only coverage. Age is in units of years; total visits in prior year are in units of ambulatory visits; and total preventable hospitalizations in prior year are in units of hospitalizations. Total visits and preventable hospitalizations in prior year refer to utilization that occurred during the 365 days before the start of a patient's observation period. Multivariate model includes Hospital Referral Region fixed effects. CHF denotes congestive heart failure; COPD denotes chronic obstructive pulmonary disease. Patients could have more than one chronic illness.