

Digital Supplement

Potentially preventable intensive care unit admissions in the United States, 2006 - 2015

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Administrative definitions

Each year of data in each database provided a different number of diagnostic codes. In order to standardize our definitions and minimize classification bias, we used only the first ten diagnostic codes even when more were available.

Intensive care unit stay

Definitions for an intensive care unit (ICU) admission are based on a prior validation study (1). A hospitalization was considered to be associated with ICU care if any of the following revenue center codes was found in the claims: 200, 201, 202, 203, 204, 207, 208, 209, 210, 211, 212, 213, 219. These revenue center codes also correspond in the MedPAR database to ICU indicator codes 0, 1, 2, 3, 4, 7, 8 and 9, and to coronary care indicator codes 0, 1, 2, 3, and 9. Notably, codes for intermediate care units were not considered in this analysis.

Ambulatory care sensitive conditions

Ambulatory care sensitivity conditions were identified based on the published definitions of Prevention Quality Indicators (PQIs) from the Agency for Health Research and Quality (2). Version 5.0 of the definition was used for all claims from 2006 through the third quarter of 2015. Version 6.0 was used in the fourth quarter of 2015 to account for the transition to ICD-10 codes. We used the standard published definitions in all cases except for PQI 13 which was retired in version 6.0 and so was excluded from our definition of version 5.0.

Life-limiting malignancy

Life-limiting malignancy was defined using the published set of ICD-9 codes (Supplemental Table 1) used in a previous study examining eligibility and enrollment in hospice services among cancer patients(3). Since no comparable definition exists for ICD-10 codes, we used the 2016 CMS General Equivalency File to generate a corresponding set of ICD-10-CM codes (Supplemental Table 2). A hospitalization was considered associated with a life-

limiting malignancy if any of the reported diagnostic codes were found in the tables below.
 The code used to generate the ICD-10-CM codes is available online:
<https://gist.github.com/gweissman/63a162b64969f56b33ce5f6e0c13f51c>

Supplemental Table E1: Previously published ICD-9-CM codes associated with a life-limiting malignancy.

ICD-9 Code	Diagnosis
1500	Malignant neoplasm of cervical esophagus
1501	Malignant neoplasm of thoracic esophagus
1502	Malignant neoplasm of abdominal esophagus
1503	Malignant neoplasm of upper third of esophagus
1504	Malignant neoplasm of middle third of esophagus
1505	Malignant neoplasm of lower third of esophagus
1508	Malignant neoplasm of other specified part of esophagus
1509	Malignant neoplasm of esophagus, unspecified site
151	Malignant neoplasm of stomach
1510	Malignant neoplasm of cardia
1511	Malignant neoplasm of pylorus
1512	Malignant neoplasm of pyloric antrum
1513	Malignant neoplasm of fundus of stomach
1514	Malignant neoplasm of body of stomach
1515	Malignant neoplasm of lesser curvature of stomach, unspecified
1516	Malignant neoplasm of greater curvature of stomach, unspecified
1518	Malignant neoplasm of other specified sites of stomach
1519	Malignant neoplasm of stomach, unspecified site
155	Malignant neoplasm of liver and intrahepatic bile ducts
1550	Malignant neoplasm of liver, primary
1551	Malignant neoplasm of intrahepatic bile ducts
1552	Malignant neoplasm of liver, not specified as primary or secondary
1570	Malignant neoplasm of head of pancreas
1571	Malignant neoplasm of body of pancreas
1572	Malignant neoplasm of tail of pancreas
1573	Malignant neoplasm of pancreatic duct
1574	Malignant neoplasm of islets of langerhans
1578	Malignant neoplasm of other specified sites of pancreas
1579	Malignant neoplasm of pancreas, part unspecified
1580	Malignant neoplasm of retroperitoneum

- 1588 Malignant neoplasm of specified parts of peritoneum
- 1589 Malignant neoplasm of peritoneum, unspecified
- 159 Malignant neoplasm of other and ill-defined sites within the digestive organs and peritoneum
- 1590 Malignant neoplasm of intestinal tract, part unspecified
- 1591 Malignant neoplasm of spleen, not elsewhere classified
- 1598 Malignant neoplasm of other sites of digestive system and intra-abdominal organs
- 1599 Malignant neoplasm of ill-defined sites within the digestive organs and peritoneum
- 1620 Malignant neoplasm of trachea
- 1622 Malignant neoplasm of main bronchus
- 1623 Malignant neoplasm of upper lobe, bronchus or lung
- 1624 Malignant neoplasm of middle lobe, bronchus or lung
- 1625 Malignant neoplasm of lower lobe, bronchus or lung
- 1628 Malignant neoplasm of other parts of bronchus or lung
- 1629 Malignant neoplasm of bronchus and lung, unspecified
- 1630 Malignant neoplasm of parietal pleura
- 1631 Malignant neoplasm of visceral pleura
- 1638 Malignant neoplasm of other specified sites of pleura
- 1639 Malignant neoplasm of pleura, unspecified
- 1641 Malignant neoplasm of heart
- 1642 Malignant neoplasm of anterior mediastinum
- 1643 Malignant neoplasm of posterior mediastinum
- 1648 Malignant neoplasm of other parts of mediastinum
- 1649 Malignant neoplasm of mediastinum, part unspecified
- 1650 Malignant neoplasm of upper respiratory tract, part unspecified
- 1658 Malignant neoplasm of other sites within the respiratory system and intrathoracic organs
- 1659 Malignant neoplasm of ill-defined sites within the respiratory system
- 191 Malignant neoplasm of brain
- 1910 Malignant neoplasm of cerebrum, except lobes and ventricles
- 1911 Malignant neoplasm of frontal lobe
- 1912 Malignant neoplasm of temporal lobe
- 1913 Malignant neoplasm of parietal lobe
- 1914 Malignant neoplasm of occipital lobe
- 1915 Malignant neoplasm of ventricles

1916 Malignant neoplasm of cerebellum nos
 1917 Malignant neoplasm of brain stem
 1918 Malignant neoplasm of other parts of brain
 1919 Malignant neoplasm of brain, unspecified
 195 Malignant neoplasm of other and ill-defined sites
 1951 Malignant neoplasm of thorax
 1952 Malignant neoplasm of abdomen
 1953 Malignant neoplasm of pelvis
 1958 Malignant neoplasm of other specified sites
 1973 Secondary malignant neoplasm of other respiratory organs
 1974 Secondary malignant neoplasm of small intestine including duodenum
 1975 Secondary malignant neoplasm of large intestine and rectum
 1976 Secondary malignant neoplasm of retroperitoneum and peritoneum
 1977 Malignant neoplasm of liver, secondary
 1978 Secondary malignant neoplasm of other digestive organs and spleen
 1980 Secondary malignant neoplasm of kidney
 1981 Secondary malignant neoplasm of other urinary organs
 1982 Secondary malignant neoplasm of skin
 1983 Secondary malignant neoplasm of brain and spinal cord
 1984 Secondary malignant neoplasm of other parts of nervous system
 1985 Secondary malignant neoplasm of bone and bone marrow
 1986 Secondary malignant neoplasm of ovary
 1987 Secondary malignant neoplasm of adrenal gland
 1988 Other specified sites
 19881 Secondary malignant neoplasm of breast
 19882 Secondary malignant neoplasm of genital organs
 19889 Secondary malignant neoplasm of other specified sites
 1990 Disseminated malignant neoplasm without specification of site
 1991 Other malignant neoplasm without specification of site
 1992 Malignant neoplasm associated with transplant organ
 20500 Acute myeloid leukemia, without mention of having achieved remission
 20502 Acute myeloid leukemia, in relapse
 20520 Subacute myeloid leukemia, without mention of having achieved remission
 20522 Subacute myeloid leukemia, in relapse
 20530 Myeloid sarcoma, without mention of having achieved remission
 20532 Myeloid sarcoma, in relapse

20580	Other myeloid leukemia, without mention of having achieved remission
20582	Other myeloid leukemia, in relapse
20590	Unspecified myeloid leukemia, without mention of having achieved remission
20592	Unspecified myeloid leukemia, in relapse
20780	Other specified leukemia, without mention of having achieved remission
20800	Acute leukemia of unspecified cell type, without mention of having achieved remission
20880	Other leukemia of unspecified cell type, without mention of having achieved remission
20890	Unspecified leukemia, without mention of having achieved remission
20892	Unspecified leukemia, in relapse
2375	Neoplasm of uncertain behavior of brain and spinal cord
23873	High grade myelodysplastic syndrome lesions
2391	Neoplasm of unspecified nature of respiratory system
2396	Neoplasm of unspecified nature of brain
78951	Malignant ascites

Supplemental Table E2: Previously published ICD-9-CM codes associated with a life-limiting malignancy converted to corresponding ICD-10-CM codes based on the CMS General Equivalency Mappings.

ICD-10

Code	Diagnosis
C153	Malignant neoplasm of upper third of esophagus
C154	Malignant neoplasm of middle third of esophagus
C155	Malignant neoplasm of lower third of esophagus
C153	Malignant neoplasm of upper third of esophagus
C154	Malignant neoplasm of middle third of esophagus
C155	Malignant neoplasm of lower third of esophagus
C158	Malignant neoplasm of overlapping sites of esophagus
C159	Malignant neoplasm of esophagus, unspecified
C160	Malignant neoplasm of cardia
C164	Malignant neoplasm of pylorus
C163	Malignant neoplasm of pyloric antrum
C161	Malignant neoplasm of fundus of stomach
C162	Malignant neoplasm of body of stomach
C165	Malignant neoplasm of lesser curvature of stomach, unspecified
C166	Malignant neoplasm of greater curvature of stomach, unspecified
C168	Malignant neoplasm of overlapping sites of stomach

C169 Malignant neoplasm of stomach, unspecified
C220 Liver cell carcinoma
C222 Hepatoblastoma
C227 Other specified carcinomas of liver
C228 Malignant neoplasm of liver, primary, unspecified as to type
C221 Intrahepatic bile duct carcinoma
C229 Malignant neoplasm of liver, not specified as primary or secondary
C250 Malignant neoplasm of head of pancreas
C251 Malignant neoplasm of body of pancreas
C252 Malignant neoplasm of tail of pancreas
C253 Malignant neoplasm of pancreatic duct
C254 Malignant neoplasm of endocrine pancreas
C257 Malignant neoplasm of other parts of pancreas
C258 Malignant neoplasm of overlapping sites of pancreas
C259 Malignant neoplasm of pancreas, unspecified
C480 Malignant neoplasm of retroperitoneum
C481 Malignant neoplasm of specified parts of peritoneum
C488 Malignant neoplasm of overlapping sites of retroperitoneum and peritoneum
C482 Malignant neoplasm of peritoneum, unspecified
C260 Malignant neoplasm of intestinal tract, part unspecified
C261 Malignant neoplasm of spleen
C269 Malignant neoplasm of ill-defined sites within the digestive system
C269 Malignant neoplasm of ill-defined sites within the digestive system
C33 Malignant neoplasm of trachea
C3400 Malignant neoplasm of unspecified main bronchus
C3410 Malignant neoplasm of upper lobe, unspecified bronchus or lung
C342 Malignant neoplasm of middle lobe, bronchus or lung
C3430 Malignant neoplasm of lower lobe, unspecified bronchus or lung
C3480 Malignant neoplasm of overlapping sites of unspecified bronchus and lung
C3490 Malignant neoplasm of unspecified part of unspecified bronchus or lung
C384 Malignant neoplasm of pleura
C384 Malignant neoplasm of pleura
C384 Malignant neoplasm of pleura
C384 Malignant neoplasm of pleura
C380 Malignant neoplasm of heart
C381 Malignant neoplasm of anterior mediastinum

C382 Malignant neoplasm of posterior mediastinum
C388 Malignant neoplasm of overlapping sites of heart, mediastinum and pleura
C383 Malignant neoplasm of mediastinum, part unspecified
C390 Malignant neoplasm of upper respiratory tract, part unspecified
C399 Malignant neoplasm of lower respiratory tract, part unspecified
C399 Malignant neoplasm of lower respiratory tract, part unspecified
C710 Malignant neoplasm of cerebrum, except lobes and ventricles
C711 Malignant neoplasm of frontal lobe
C712 Malignant neoplasm of temporal lobe
C713 Malignant neoplasm of parietal lobe
C714 Malignant neoplasm of occipital lobe
C715 Malignant neoplasm of cerebral ventricle
C716 Malignant neoplasm of cerebellum
C717 Malignant neoplasm of brain stem
C718 Malignant neoplasm of overlapping sites of brain
C719 Malignant neoplasm of brain, unspecified
C761 Malignant neoplasm of thorax
C762 Malignant neoplasm of abdomen
C763 Malignant neoplasm of pelvis
C768 Malignant neoplasm of other specified ill-defined sites
C7839 Secondary malignant neoplasm of other respiratory organs
C784 Secondary malignant neoplasm of small intestine
C785 Secondary malignant neoplasm of large intestine and rectum
C786 Secondary malignant neoplasm of retroperitoneum and peritoneum
C787 Secondary malignant neoplasm of liver and intrahepatic bile duct
C787 Secondary malignant neoplasm of liver and intrahepatic bile duct
C7889 Secondary malignant neoplasm of other digestive organs
C7900 Secondary malignant neoplasm of unspecified kidney and renal pelvis
C7911 Secondary malignant neoplasm of bladder
C7919 Secondary malignant neoplasm of other urinary organs
C792 Secondary malignant neoplasm of skin
C7931 Secondary malignant neoplasm of brain
C7932 Secondary malignant neoplasm of cerebral meninges
C7949 Secondary malignant neoplasm of other parts of nervous system
C7951 Secondary malignant neoplasm of bone
C7952 Secondary malignant neoplasm of bone marrow

C7960 Secondary malignant neoplasm of unspecified ovary
 C7970 Secondary malignant neoplasm of unspecified adrenal gland
 C7981 Secondary malignant neoplasm of breast
 C7982 Secondary malignant neoplasm of genital organs
 C7989 Secondary malignant neoplasm of other specified sites
 C800 Disseminated malignant neoplasm, unspecified
 C801 Malignant (primary) neoplasm, unspecified
 C802 Malignant neoplasm associated with transplanted organ
 C9200 Acute myeloblastic leukemia, not having achieved remission
 C9240 Acute promyelocytic leukemia, not having achieved remission
 C9250 Acute myelomonocytic leukemia, not having achieved remission
 C9202 Acute myeloblastic leukemia, in relapse
 C9242 Acute promyelocytic leukemia, in relapse
 C9252 Acute myelomonocytic leukemia, in relapse
 C9220 Atypical chronic myeloid leukemia, BCR/ABL-negative, not having achieved remission
 C9222 Atypical chronic myeloid leukemia, BCR/ABL-negative, in relapse
 C9230 Myeloid sarcoma, not having achieved remission
 C9232 Myeloid sarcoma, in relapse
 C92Z0 Other myeloid leukemia not having achieved remission
 C92Z2 Other myeloid leukemia, in relapse
 C9290 Myeloid leukemia, unspecified, not having achieved remission
 C9292 Myeloid leukemia, unspecified in relapse
 C9430 Mast cell leukemia not having achieved remission
 C9480 Other specified leukemias not having achieved remission
 C9500 Acute leukemia of unspecified cell type not having achieved remission
 C9590 Leukemia, unspecified not having achieved remission
 C9590 Leukemia, unspecified not having achieved remission
 C9592 Leukemia, unspecified, in relapse
 D432 Neoplasm of uncertain behavior of brain, unspecified
 D434 Neoplasm of uncertain behavior of spinal cord
 D4622 Refractory anemia with excess of blasts 2
 D491 Neoplasm of unspecified behavior of respiratory system
 D496 Neoplasm of unspecified behavior of brain
 R180 Malignant ascites

Additional Results

Association with ICU Beds

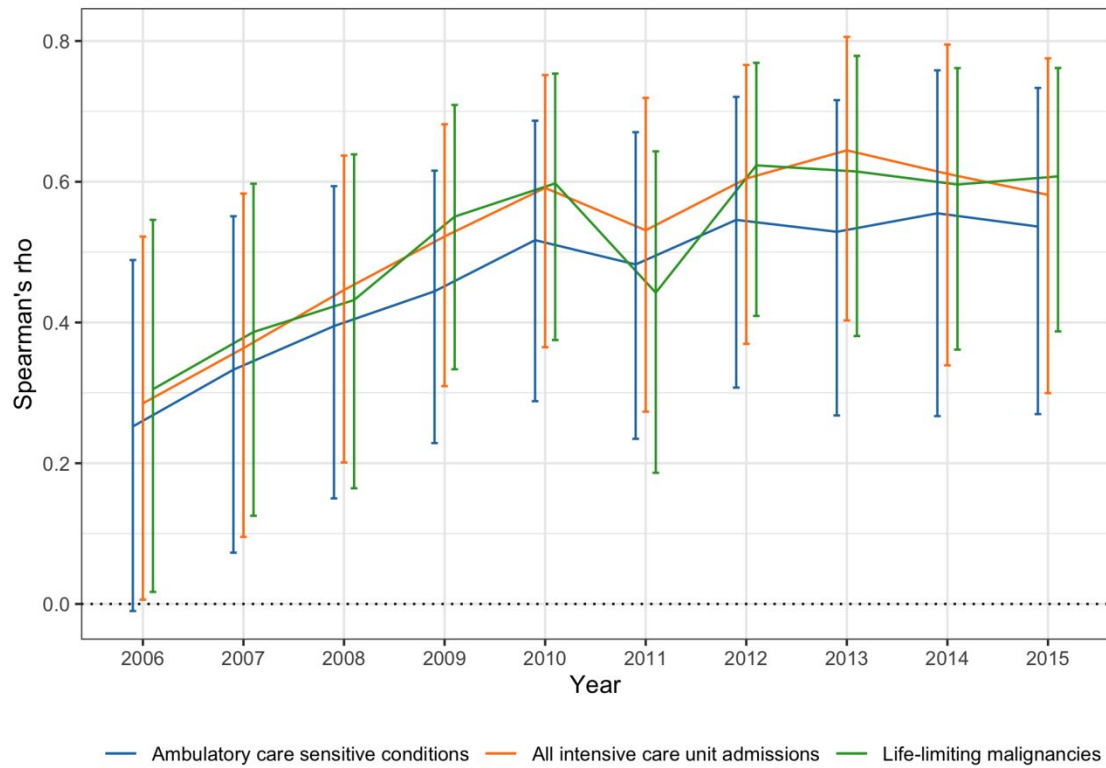


Figure E1: Correlation between available ICU beds and potentially preventable hospitalizations requiring ICU care across states.

The following figures E2 and E3 are presented as a visual check that the bootstrapped distributions of the differences in correlations were roughly normally distributed.

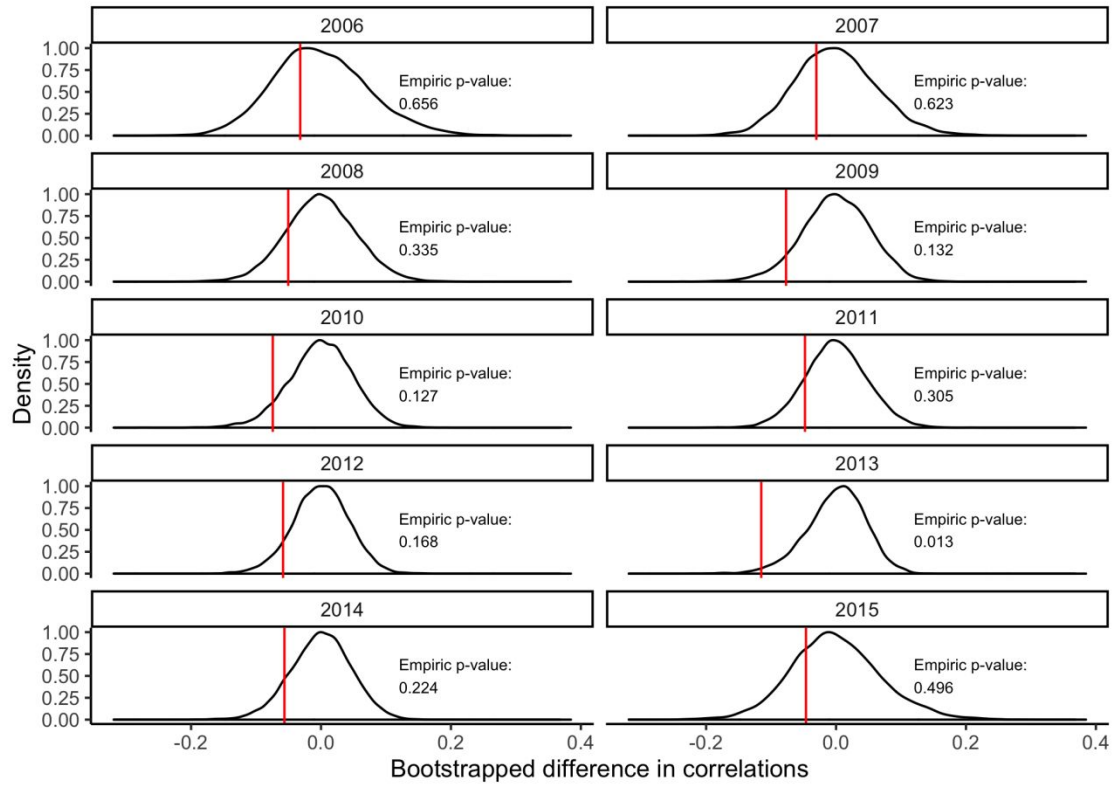


Figure E2: A bootstrapped estimate of the difference between correlation between ICU beds and all ICU admissions, and between ICU beds and ICU admissions associated with ACSC was calculated with 10,000 replicates. The distribution of differences between these values was mean-normalized across each year.

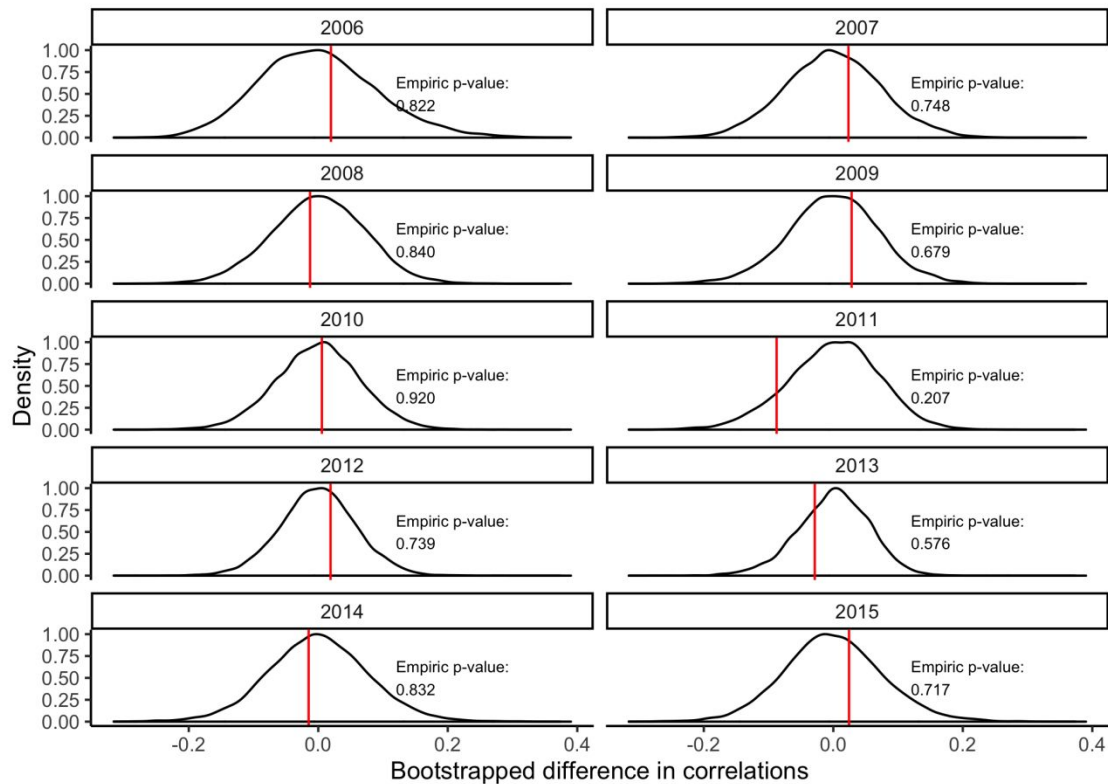


Figure E3: A bootstrapped estimate of the difference between correlations between ICU beds and all ICU admissions, and between ICU beds and ICU admissions associated with LLMs was calculated with 10,000 replicates. The distribution of differences between these values was mean-normalized across each year.

State comparisons

We calculated geographic differences at the state level (including Washington, DC, and Puerto Rico) in the MedPAR database. For between-state comparisons, we adjusted admission rates based on 2010 US Census data for each states' population distribution of age and gender (4). We identified the quintile of states with the lowest proportion of ICU admissions associated with each potentially preventable diagnosis. The following figures E4 and E5 demonstrate the state-level heterogeneity in admission rates, and use the lowest-admitting states to provide a conservative reference point for what a hypothetical floor on such a value might look like.

We observed a two-fold variation among states in potentially preventable ICU admissions in the FFS population (XXX). Among hospitalizations with ICU care, the average proportion with an ACSC ranged from 9.2% (95% CI 8.9 - 9.6) in North Dakota to 21.4% (95% CI 21.0 - 21.8) in Puerto Rico. The average proportion of hospitalizations with ICU care associated with a LLM ranged from 3.9% (95% CI 3.7 - 4.1) in Puerto Rico to 7.6% (95% CI 7.3 - 7.9) in Delaware.

Among hospitalizations associated with an ICU admission in the lowest quintile of states by ICU admission rates in the FFS population, 11.8% were for ACSCs (Supplemental Figure E4)

and 5.0% for LLMs (Supplemental Figure E5). If these estimates represented a lower-bound on achievable admission rates, we would still have observed 59,024 and 19,581 average yearly preventable hospital admissions with ICU care in the remaining states for ACSCs and LLMs, respectively.

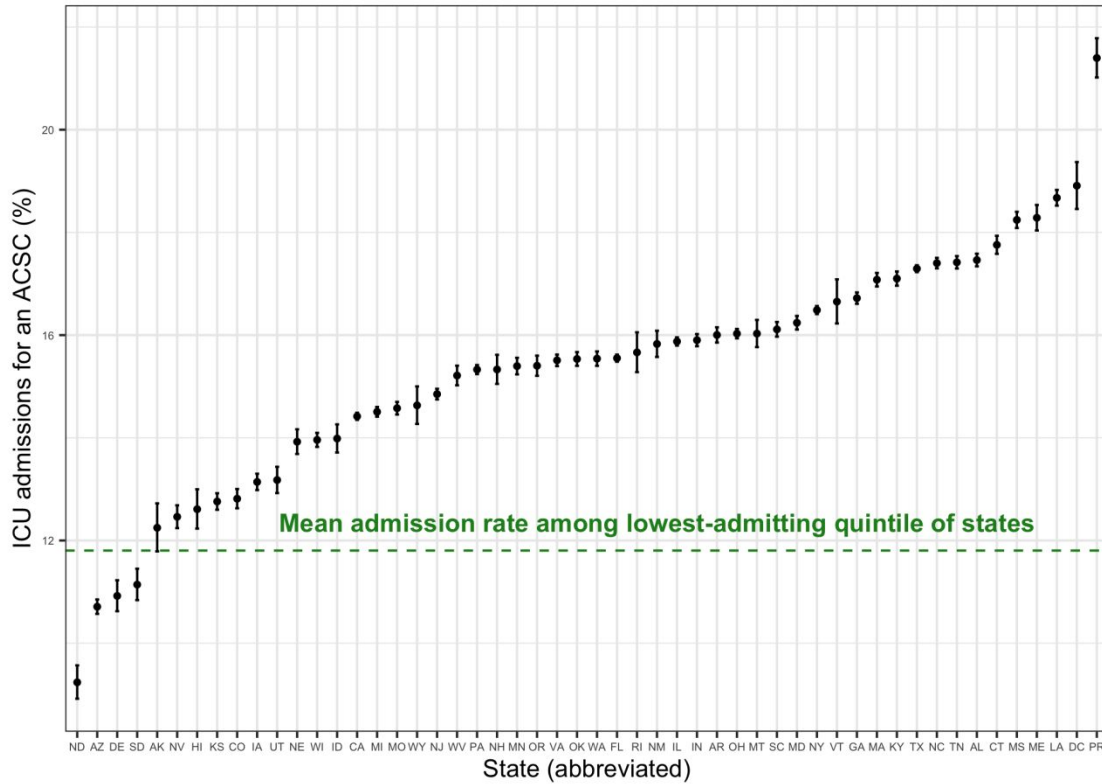


Figure E4: Variation in the percentage of intensive care unit (ICU)-associated hospitalizations with administrative codes for ambulatory care sensitive conditions (ACSCs). Green dotted line indicates the mean admission rate among the lowest-admitting quintile of states.

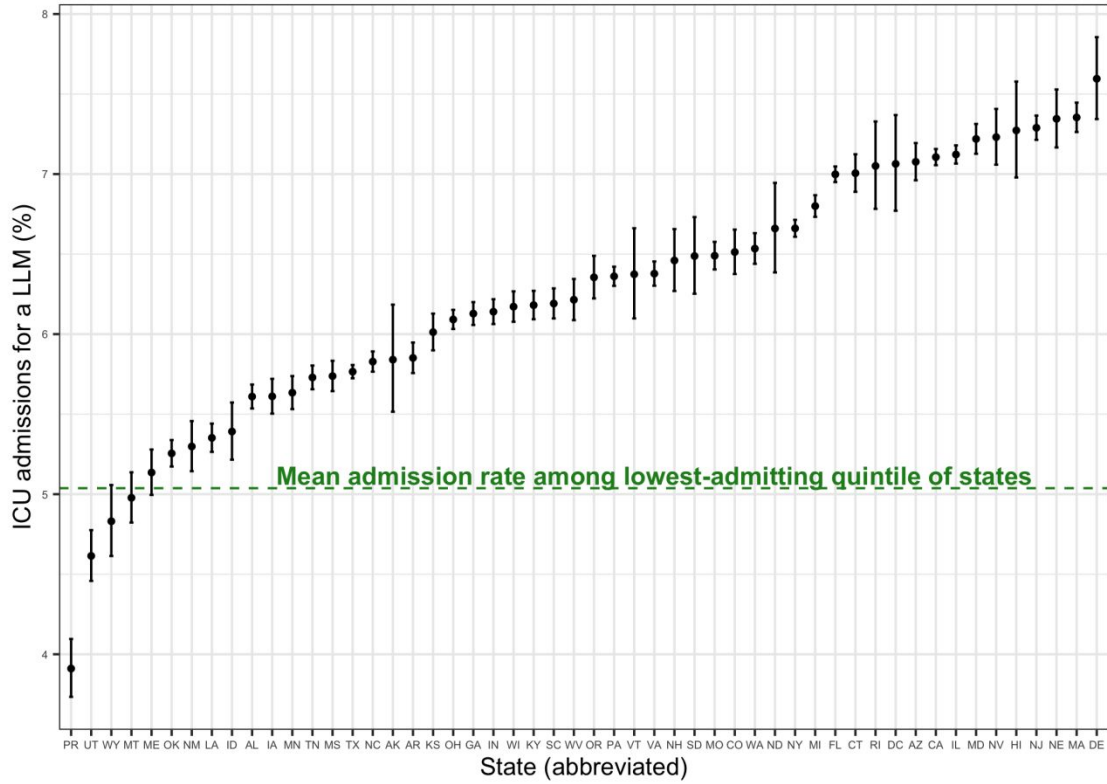


Figure E5: Variation in the percentage of intensive care unit (ICU)-associated hospitalizations with administrative codes for life-limiting malignancies (LLMs). Green dotted line indicates the mean admission rate among the lowest-admitting quintile of states.

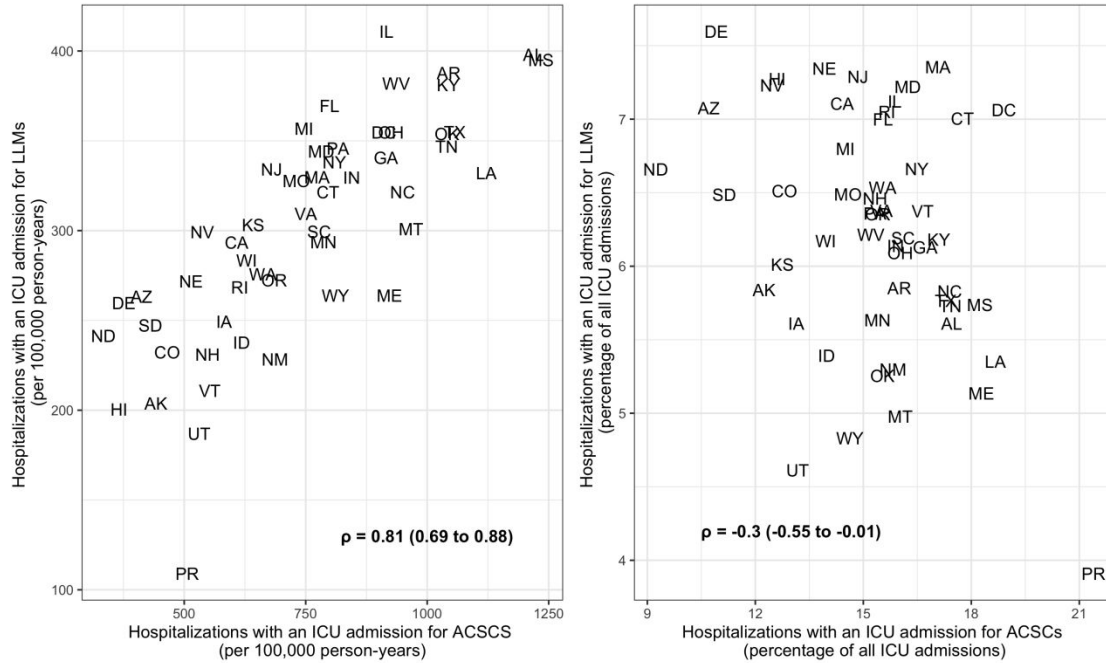


Figure E6: State-level differences in rates of intensive care unit (ICU) admissions for a potentially preventable cause among Medicare Fee-for-Service beneficiaries at least 65 years old adjusted for the age and gender distribution in each state (left panel), and as an unadjusted percentage of all ICU admissions (right panel). The y-axis shows admissions for life-limiting malignancies (LLMs) and the x-axis shows those for ambulatory care sensitive conditions (ACSCs). Correlations represent averages over the ten-year study period. Notably, state populations change relatively little while available ICU beds for admissions change rapidly and heterogeneously across states.

Sensitivity analysis

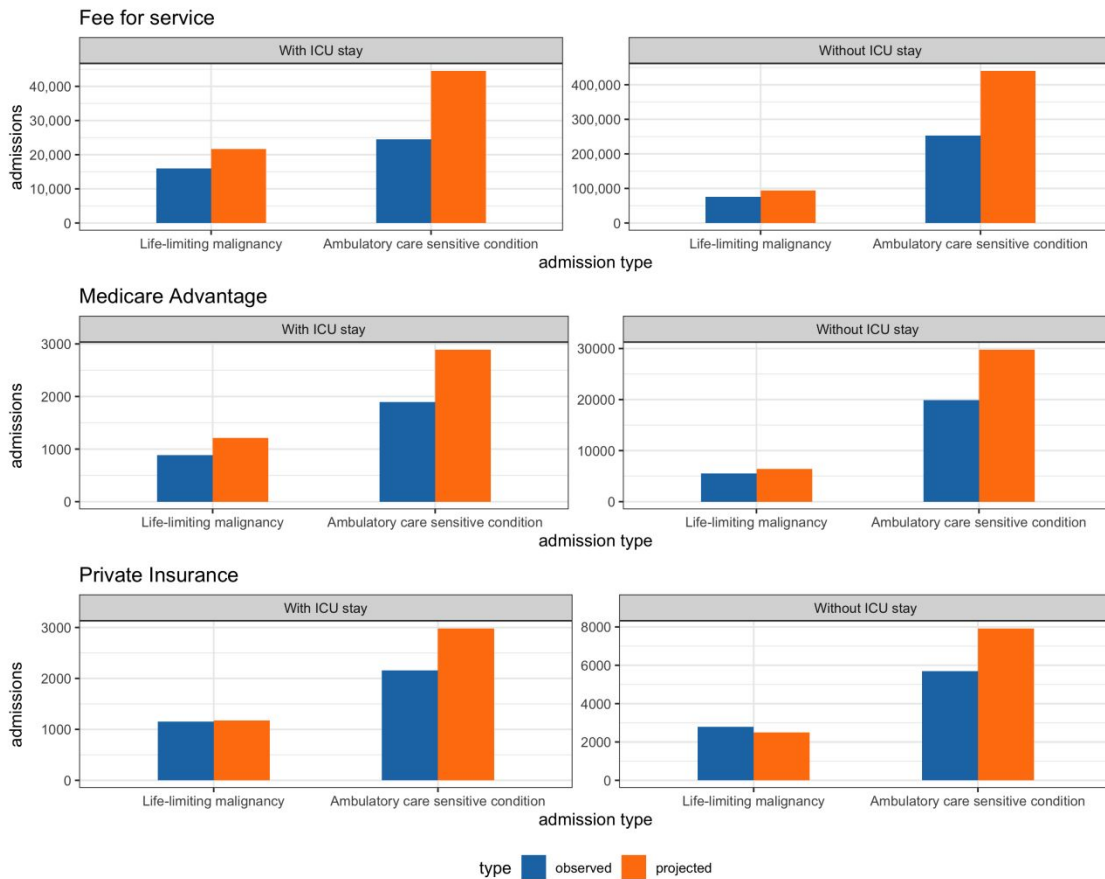


Figure E7: Sensitivity analysis results. Comparison of the observed and projected admission types in the fourth quarter of 2015. While observed and projected admissions differed substantially, the overall ten-year trends when calculated using the projected rates did not meaningfully differ.

Admissions by age among those with private insurance

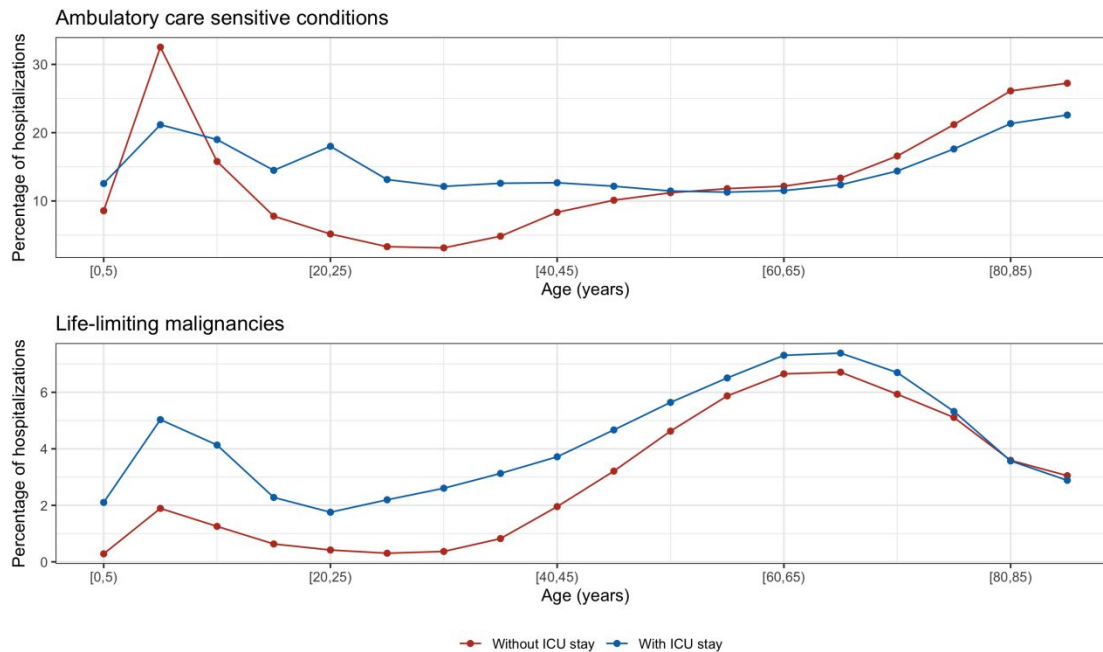


Figure E8: Among those with private insurance, the proportion of potentially preventable hospitalizations by age, stratified by whether or not the hospitalization was associated with an intensive care unit (ICU) stay. Notably, the privately insured cohort includes patients from newborns through age 65, in addition to those over 65.

References

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