Variation in Postsepsis Readmission Patterns: A Cohort Study of Veterans Affairs Beneficiaries

Hallie C. Prescott[1,2]

[1]VA Center for Clinical Management Research, Health Services Research and Development Service Center of Innovation, VA Ann Arbor Healthcare System, Ann Arbor, Michigan; and [2]Department of Medicine, Division of Pulmonary and Critical Care Medicine, Institute for Health Policy and Innovation, University of Michigan, Ann Arbor, Michigan

ORCID ID: 0000-0002-8442-6724 (H.C.P.).

Abstract

Rationale: Rehospitalization is common after sepsis, but little is known about the variation in readmission patterns across patient groups and care locations.

Objectives: To examine the variation in postsepsis readmission rates and diagnoses by patient age, nursing facility use, admission year, and hospital among U.S. Veterans Affairs (VA) beneficiaries.

Methods: Observational cohort study of VA beneficiaries who survived a sepsis hospitalization (2009–2011) at 114 VA hospitals, stratified by age (<65 vs. ≥65 yr), nursing home usage (none, chronic, or acute), year of admission (2009, 2010, 2011), and hospital. In the primary analysis, sepsis hospitalizations were identified using a previously validated method. Sensitivity analyses were performed using alternative definitions with explicit *International Classification of Diseases, Ninth Revision, Clinical Modification*, codes for sepsis, and separately for severe sepsis and septic shock.

Measurements and Main Results: The primary outcomes were rate of 90-day all-cause hospital readmission after sepsis hospitalization and proportion of readmissions resulting from specific diagnoses, including the proportion of "potentially preventable" readmissions. Readmission diagnoses were similar from 2009 to 2011, with little variation in readmission rates across hospitals. The top six readmission diagnoses (heart failure, pneumonia, sepsis, urinary tract infection, acute renal failure, and chronic obstructive pulmonary disease) accounted for 30% of all readmissions. Although about one in five readmissions had a principal diagnosis for infection, 58% of all readmissions received early systemic antibiotics. Infection accounted for a greater proportion of readmissions among patients discharged to nursing facilities compared with patients discharged to home (25.0–27.1% vs. 16.8%) and among older vs. younger patients (22.2% vs. 15.8%). Potentially preventable readmissions accounted for a quarter of readmissions overall and were more common among older patients and patients discharged to nursing facilities.

Conclusions: Hospital readmission rates after sepsis were similar by site and admission year. Heart failure, pneumonia, sepsis, and urinary tract infection were common readmission diagnoses across all patient groups. Readmission for infection and potentially preventable diagnoses were more common in older patients and patients discharged to nursing facilities.

Keywords: sepsis; hospitalization; patient readmission; skilled nursing facility; patient outcomes assessment

Each year in the United States, hundreds of thousands of patients survive hospitalization for sepsis (1, 2). These survivors use significant health care resources in the year after sepsis, even relative to their own personal presepsis use (3). In particular, sepsis survivors experience high rates of hospital readmission in the first 90 days after discharge, often returning to the hospital for potentially preventable diagnoses (4).

However, although the existing studies document a high rate of postsepsis readmissions in a variety of patient populations (4–9), there is little understanding of how readmission patterns may vary by individual patient characteristics, over time, and by hospital. The high proportion of readmissions resulting from a small number of potentially preventable diagnoses suggests that postdischarge interventions could be tailored toward an individual patient's risk for a select number of diagnosis-specific readmissions (4). However, for risk-tailored interventions to be helpful and feasible, there must be meaningful differences in risk for diagnosis-specific readmissions across patients, and readmission patterns must be relatively stable over time.

In this study, I examined the rate and principal diagnoses of postsepsis hospital readmissions within the U.S. Department of Veterans Affairs (VA) health care system. To assess how readmission patterns vary across different clinical scenarios, I stratified analyses separately by veteran age, by nursing facility use, by year of hospital admission, and by hospital.

Methods

Identification of Sepsis Hospitalizations
I identified all VA beneficiaries hospitalized with sepsis at any of 114 VA hospitals during 2009–2011, using the method of Angus and colleagues (concurrent *International Classification of Diseases, Ninth Revision, Clinical Modification* [ICD-9-CM], codes for infection and acute organ dysfunction) (10). This method has been validated within the private sector and found to have excellent specificity and greater sensitivity than other claims-based methods (11). Our research group has validated this method against structured chart review within the VA and confirmed that the sensitivity and specificity of this method are similar to the private sector (*see* online supplement). This definition reflects the third international consensus definition that sepsis is "life-threatening organ dysfunction caused by a dysregulated response to host infection" (12), or what the previous sepsis definition conceptualized as "severe sepsis" (13).

For patients with multiple sepsis hospitalizations, just the first admission for each calendar year was included in the analytic cohort. Sensitivity analyses examined readmissions after both hospitalizations with explicitly coded sepsis (ICD-9-CM code 995.91) and hospitalizations with explicitly coded severe sepsis or sepsis shock (ICD-9-CM codes 995.92 or 785.52).

Identification of Hospital Readmissions
Because many veterans use health care outside of the VA system (14–16), I examined claims not only from VA hospitalizations but also from VA-funded care delivered outside of the VA ("fee-based" care) and Medicare-funded care to identify hospitalizations within 90 days of discharge from sepsis hospitalization, including claims from hospitals outside the VA. Hospitalizations that occurred within 1 day of a hospital discharge were merged and considered a single hospitalization with an interhospital transfer.

Readmission Diagnoses
Hospital readmissions were assigned to one mutually exclusive diagnosis category according to the principal ICD-9-CM code from the hospital claim, using the Healthcare Cost and Utilization Project's (HCUP's) Clinical Classification Software (17). For hospitalizations with an interhospital transfer, the principal diagnosis from the first hospital claim was used for classification.

Patient Subgroups
I examined unadjusted readmission rates and diagnoses by year of hospital admission (2009, 2010, and 2011), by patient age at hospital admission (<65 vs. ≥65 yr), and by nursing facility use among patients with a 2009 sepsis hospitalization. I also examined adjusted rates of readmission by hospital. Nursing facility use was classified as none, chronic nursing facility use (patient in a nursing home before and after sepsis hospitalization), or acute nursing facility use (patient in a nursing home after, but not before, sepsis hospitalization).

Unadjusted Analyses: Patient Age, Nursing Home Use, Admission Year
For subgroups defined by patient age, nursing facility use, and admission year, I calculated rates of hospital readmission, mortality, and readmission or mortality at 30 and 90 days after live discharge from sepsis hospitalization.

To understand the relative importance of individual diagnoses to the overall burden of readmissions, and to facilitate comparisons across subgroups with different absolute rates of readmission, I identified the 10 diagnoses that accounted for the greatest proportion of the total 90-day readmissions for each subgroup. Conceptually, this analysis answers the question: "Of all readmissions after sepsis, how many were due to X?" I also present 90-day diagnosis-specific readmission rates in the online supplement, answering the related question: "Of patients who survive sepsis, how many come back to the hospital with X?" I also determined the proportion of readmissions resulting from infection (HCUP diagnosis category of sepsis, pneumonia, urinary tract infection, skin/soft tissue infection, or intestinal infection).

To gauge the potential preventability of readmissions, I determined the proportion of readmissions that were for ambulatory care sensitive conditions (ACSCs) recognized by the Agency for Healthcare Research and Quality (18), and using an expanded definition that also included sepsis, skin and soft tissue infection, acute renal failure, and aspiration pneumonitis, all of which could plausibly be prevented and/or treated early to avoid rehospitalization (4).

Because HCUP diagnosis categories may underestimate the role of infection in readmissions, I also measured the proportion of readmissions to the VA that were treated with at least one systemic antibiotic (i.e., excluding topical, inhaled, or ophthalmologic antibiotics) during at least 1 of the first 2 calendar days of readmission. The rate of early systemic antibiotics is a liberal estimate of the rate of infection at time of hospital readmission.

To assess the heterogeneity of readmission diagnoses by subgroup, I determined the percentage of total readmissions that were accounted for by the top 10 readmission diagnoses. I also present an ordered bar graph of readmission diagnoses among patients with a 2009 sepsis hospitalization to visually display the range of readmission diagnoses and the proportion accounted for by the top one, ten, 50, and so on, diagnoses.

Because of the large numbers of veterans in the study, even small, clinically insignificant differences in rates of

readmission are statistically significant. For this reason, I do not present *P* values with any of the analyses. When comparing subgroups, I considered a 2% absolute difference in the proportion of readmissions resulting from a specific condition to be clinically significant (and in each case, these differences were also statistically significant). However, I present the full data in the tables to allow readers to draw their own conclusions from the data.

Adjusted Analyses: Site

Using hierarchical logistic regression with patients nested within hospitals, I measured risk- and reliability-adjusted rates of all-cause readmission by hospital for each hospital with more than 25 live sepsis discharges in 2011. I present these data as a caterpillar plot. Risk adjustment accounted for severity of illness on hospital admission, using a previously described composite score similar to APACHE IV (19–21), age, race, weighted count of chronic comorbidities (22, 23), and length of hospitalization. Reliability adjustment is a routine procedure for hospital quality reporting that accounts for the uncertainty of estimates for smaller hospitals (24–26). Hospitals with fewer observations have their readmission rate "shrunk" toward the average, removing the statistical noise associated with small sample sizes.

To quantify the variation in risk-adjusted readmission rates across hospitals, I calculated the intraclass correlation coefficient (ICC), the median odds ratio (MOR), and the absolute difference in readmission rate between the median hospital in the best and worse quintiles of readmission performance. The ICC is interpreted as the proportion of variance explained by a given level of aggregation; in this case, the hospital (27). The MOR represents the median increase in odds of readmission that would result from transferring a patient from the better to the worse of two randomly selected hospitals (27). A MOR of 1.0 implies that the risk for readmission is equivalent across all hospitals. The greater the MOR, the more important the hospital is to driving differences in readmission.

All analyses were conducted with Stata MP 14.1 (StataCorp, College Station, TX). Patient and hospitalization characteristics are presented as medians (interquartile ranges) or numbers (percentages). This study was approved by the Ann Arbor VA

institutional review board with a waiver of informed consent.

Results

Patient and Hospitalization Characteristics

In 2009, 32,936 patients were hospitalized with sepsis, followed by 36,732 in 2010 and 39,271 in 2011 (Tables 1 and 2), of whom 28,618 (86.9%), 32,285 (87.8%), and 34,840 (88.7%) survived to hospital discharge, respectively. Of the 28,618 patients surviving hospitalization in 2009, 22,378 (78.2%) were discharged to home, 1,669 (5.8%) were discharged to a nursing facility on a chronic basis, and 3,901 (13.6%) were discharged to a nursing facility on an acute basis. The patients were predominantly white (72%) and male (97%) and had a median age of 69 years. Crude in-hospital mortality varied from 13.1% (95% confidence interval [CI], 12.7–13.5%) in 2009 to 11.3% (95% CI, 11.0–11.6%) in 2011. Patient and hospitalization characteristics by age and discharge location are presented in Table E2 and Table E3 in the online supplement.

Patterns of Hospital Readmission by Patient Age

The proportion of patients experiencing a 90-day hospital readmission was 37.3% (95% CI, 36.4–38.2%) among patients younger than 65 years and 39.2% (95% CI, 38.4–39.9%) among patients aged 65 years or older. Congestive heart failure and urinary tract infections were more common in elderly patients (8.4% and 5.8% of readmissions, respectively, vs. 5.0% and 3.0% of readmissions in younger patients, respectively; Figure 1; Figure E1). Liver

disease was more common in younger patients (4.0% of readmissions vs. 0.7% in older patients). Overall, infection accounted for 22.2% of readmissions in elderly patients compared with 15.8% in younger patients. ACSCs accounted for a greater proportion of the readmissions in older vs. younger patients, using both the AHRQ definition (29.9% vs. 22.7%) and the expanded definition (43.1% vs.34.4%).

The top 10 diagnoses accounted for 44.8% of readmissions in patients aged 65 years and older, but just 36.9% of readmissions in patients less than 65 years old. Diagnosis-specific rates of readmission by patient age group are presented in Table E4.

Patterns of Hospital Readmission by Nursing Facility Use

As anticipated, the proportion of patients experiencing a 90-day hospital readmission differed significantly by discharge location, from 36.5% (95% CI, 35.9–37.2%) among patients discharged to home to 45.1% (95% CI, 42.7–47.5%) among patients discharged to nursing facility on a chronic basis and 46.8% (95% CI, 45.2–48.4%) among patients discharged to a nursing facility on an acute basis. Readmission outcomes also differed by nursing facility usage. Rates of 90-day mortality (from initial discharge) among those with a readmission were 27.4% in acute nursing home patients, 26.1% in chronic nursing home patients, and 18.9% in patients without nursing home use (Table E5).

The most common readmission diagnoses differed by nursing facility use (Figure 2). Sepsis was more common in patients discharged to a facility (8.3% of readmissions among patients discharged to

Table 1. Characteristics of patients with sepsis hospitalization by year

Sepsis Hospitalizations	2009 (N = 32,936)	2010 (N = 36,732)	2011 (N = 39,271)
Age, median (interquartile range), yr	69 (60–80)	69 (61–80)	68 (62–80)
Male, N (%)	31,928 (96.9)	35,936 (96.9)	38.082 (97.0)
Race, N (%)			
White/Caucasian	23,597 (71.6)	26,466 (72.1)	28,409 (72.3)
Black/African American	6,052 (18.4)	6,652 (18.1)	7,361 (18.7)
Other or unknown	3,287 (10.0)	3,614 (9.8)	3,501(8.9)
Total hospital length of stay, median (interquartile range), d	7 (4–14)	7 (4–14)	7 (3–13)
Intensive care unit use, N (%)	13,561 (41.2)	14,273 (38.9)	14,871 (37.9)
Intensive care unit and mechanically ventilated, N (%)	5,604 (17.1)	5,919 (16.1)	6.035 (15.4)
In-hospital mortality, N (%)	4,318 (13.1)	4,447 (12.1)	4,431 (11.3)

Table 2. Outcomes among patients with sepsis who survive to hospital discharge by year

Outcomes	2009 (N = 28,618)	2010 (N = 32,285)	2011 (N = 34,840)
30-day readmission, N (%)	6,296 (22.0)	6,855 (21.2)	6,850 (19.7)
30-day mortality, N (%)	2,701 (9.4)	2,868 (8.9)	3,057 (8.8)
30-day readmission or mortality, N (%)	8,275 (28.9)	9,035 (28.0)	9,248 (26.5)
90-day readmission, N (%)	10,984 (38.4)	11,895 (36.8)	11,941 (34.3)
90-day mortality, N (%)	4,896 (17.1)	5,297 (16.4)	5,728 (16.4)
90-day readmission or mortality, N (%)	13,652 (47.7)	14,899 (46.2)	15,400 (44.2)

a nursing facility on a chronic basis and 8.2% of readmissions among patients to a nursing facility on an acute basis vs. 3.5% of readmissions among patients discharged to home). Urinary tract infection (9.1% of readmissions), acute respiratory failure (4.8% of readmissions), and aspiration pneumonitis (4.6% of readmissions) were more common in patients discharged to a nursing facility on a chronic basis than to patients discharged to home (4.2%, 2.0%, and 1.1% of readmissions, respectively). In total, the proportion of readmissions resulting from infection was much greater among patients discharged to nursing facilities on a chronic basis (27.1%) or an acute basis (25.0%) compared with patients discharged to home (16.8%). Rates of early systemic antibiotic use were also much higher in patients discharged to nursing homes (70.3% for chronic, 64.6% for acute) than to home (56.0%) (Table E6).

The proportion of readmissions resulting from ACSCs was similar by nursing facility use with the AHRQ definition (27.4% vs.

27.3% vs. 25.3%), but varied with the expanded definition (38.4% of readmissions in patients discharged home vs. 44.3% in patients discharged to a nursing facility on a chronic basis, and 42.3% in patients discharged to a nursing facility on an acute basis).

The top 10 readmission diagnoses accounted for 50.5% of readmissions among patients discharged to a chronic nursing facility, 46.4% of readmissions among patients discharged to a nursing facility acutely, and 39.0% of readmissions among patients discharged to home, suggesting that the reasons for hospital readmission are less heterogeneous among patients in nursing facilities. Diagnosis-specific rates of readmission by nursing facility use are presented in Table E7.

Patterns of Hospital Readmission by Admission Year

The proportion of patients experiencing a 90-day readmission ranged from 38.4% (95% CI, 37.8–38.9%) in 2009 to 34.3% (95% CI, 33.8–34.8%) in 2011 (Tables 1 and 2). Six diagnoses accounted for 30.0–30.4%

of readmissions, whereas 10 diagnoses accounted for 40.6–40.8% of readmissions during 2009–2011 (Figure 3). The same 10 diagnoses accounted for the highest proportion of readmissions during each year, with little change year to year (Figure 4; Figure E1). Infection accounted for 16.6–16.9% of readmissions. ACSCs accounted for 26.4–27.1% of readmissions using the AHRQ definition, and 39.2–39.7% of readmissions using the expanded definition. Diagnosis-specific rates of readmission by year are presented in Table E8.

Patterns of Hospital Readmission by Site

There was little variation in all-cause readmission across hospitals within the VA (Figure 5). The rate of readmission for the median hospital in the bottom quintile was 30.1% (95% CI, 30.0–30.1%) vs. 35.0% (95% CI, 35.0–35.0%) for the median hospital in the best-performing quintile. The intraclass correlation coefficient was 0.4%, suggesting that very little of the variation in outcome across patients is caused by the hospital where the patient was treated. Similarly, the median odds ratio for readmission was 1.11, again suggesting there is little variation in odds of readmission across sites.

Sensitivity Analyses

Rates of readmission varied slightly depending on the method of identifying sepsis (Table E9). Patients with an explicit diagnosis for sepsis had a higher in-hospital mortality rate than patients with an implicit diagnosis of sepsis; patients with an explicit

	Age <65 years (N = 6,546 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)	Age ≥65 years (N = 9,290 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)
1	Congestive heart failure (5.0%)	Congestive heart failure (8.4%)
2	Pneumonia (4.5%)	Pneumonia (6.0%)
3	Acute renal failure (4.3%)	Urinary tract infection (5.8%)
4	Sepsis (4.0%)	Sepsis (5.3%)
5	Liver disease (4.0%)	Chronic obstructive pulmonary disease (4.5%)
6	Chronic obstructive pulmonary disease (3.2%)	Acute renal failure (4.4%)
7	Complications of medical or surgical care (3.2%)	Complication of device, implant, graft (2.8%)
8	Urinary tract infection (3.0%)	Acute respiratory failure (2.7%)
9	Diabetes with complication (3.0%)	Fluid/electrolyte disorder (2.7%)
10	Complication of device, implant, graft (2.9%)	Intestinal infection (2.5%)

Figure 1. Top 10 readmission diagnoses after hospitalization for sepsis, by age. Readmission diagnoses are color-coded to facilitate easier comparison across the three subgroups. The top 10 diagnoses in 2009 were assigned a shade from *blue* to *green*, and these same color assignments were applied to subgroups by age grouping. Diagnoses in the top 10 for individual subgroups that were not in the top 10 diagnoses overall for 2010 are shown in shades of *orange*.

	None (N = 11,911 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)	Chronic nursing facility (N = 1,061 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)	Acute nursing facility (N = 2,524 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)
1	Congestive heart failure (7.4%)	Urinary tract infection (9.1%)	Sepsis (8.2%)
2	Pneumonia (4.8%)	Sepsis (8.3%)	Pneumonia (7.2%)
3	Chronic obstructive pulmonary disease (4.5%)	Pneumonia (6.5%)	Congestive heart failure (6.0%)
4	Acute renal failure (4.3%)	Acute respiratory failure (4.8%)	Acute renal failure (5.3%)
5	Urinary tract infection (4.2%)	Congestive heart failure (4.7%)	Urinary tract infection (5.0%)
6	Sepsis (3.5%)	Aspiration pneumonitis (4.6%)	Acute respiratory failure (3.5%)
7	Complication of device, implant, graft (2.7%)	Complication of device, implant, graft (3.9%)	Complication of device, implant or graft (3.1%)
8	Complication of surgical or medical care (2.7%)	Acute renal failure (3.3%)	Complication of surgical or medical care (3.1%)
9	Fluid/electrolyte disorder (2.7%)	Fluid/electrolyte disorder (2.9%)	Intestinal infection (2.7%)
10	Diabetes with complication (2.3%)	Anemia (2.5%)	Chronic obstructive pulmonary disease (2.5%)

Figure 2. Top 10 readmission diagnoses after hospitalization for sepsis, by nursing facility use. Readmission diagnoses are color-coded to facilitate easier comparison across the three subgroups. The top 10 diagnoses in 2009 were assigned a shade from *blue* to *green*, and these same color assignments were applied to subgroups by nursing facility usage. Diagnoses in the top 10 for individual subgroups that were not in the top 10 diagnoses overall for 2010 are shown in shades of *orange*.

diagnosis of severe sepsis or septic shock had the greatest in-hospital mortality. Rates of readmission and postdischarge mortality followed these same general trends, being highest in patients with explicit severe sepsis or septic shock and lowest in patients with implicit sepsis. Despite differences in the rate of readmission, the most common readmission diagnoses were largely similar, but with a higher proportion of readmissions for infection and sepsis after explicitly coded sepsis hospitalizations (Table E10).
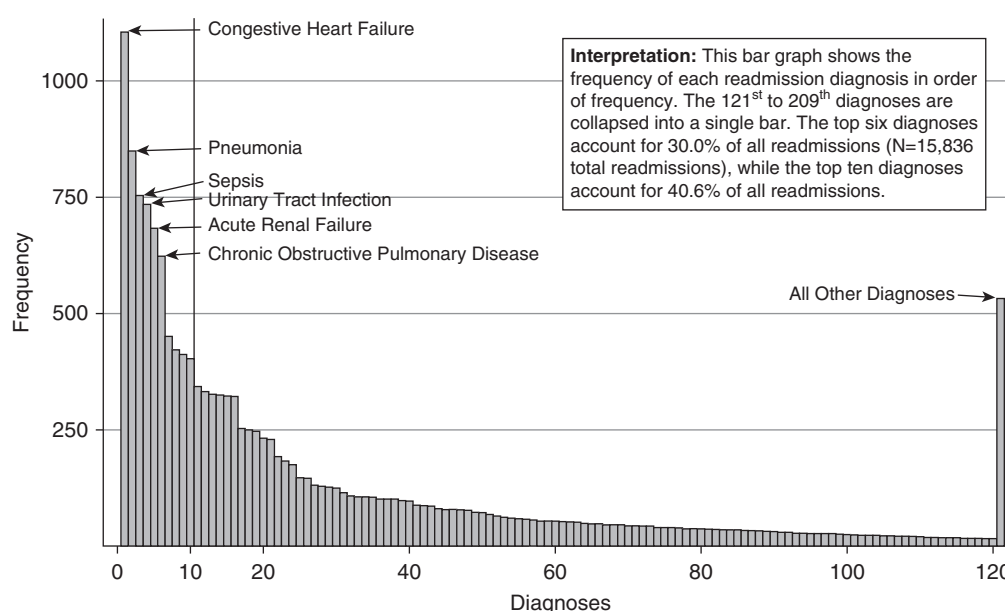
Discussion

In this study of all VA sepsis hospitalizations in 2009–2011, patterns of hospital readmission after sepsis are largely stable year to year and site to site. The top six readmission diagnoses (congestive heart failure, pneumonia, sepsis, urinary tract infection, acute renal failure, and chronic obstructive pulmonary disease) were stable over time and accounted for about one in three readmissions after sepsis. These top six diagnoses were also common across important clinical subgroups defined by age and nursing facility usage.

However, there were important differences in readmissions patterns by patient subgroups. Infection was a more common cause of readmission among patients residing in a nursing facility after sepsis, accounting for one-fourth of all readmissions in this subgroup. Congestive heart failure, urinary tract infection, and infection in general were more common readmission diagnoses in older patients, whereas liver disease was more common in younger patients. A greater proportion of the readmissions were for ACSCs in older patients vs. younger patients, which is largely explained by admissions for congestive heart failure and urinary tract infection. Hospital readmission diagnoses were also more homogenous in older patients and, in particular, in patients residing in a nursing facility, where the top 10 diagnoses account for about half of all readmissions.

Figure 3. Ordered bar graph of diagnoses of all 90-day readmissions after 2009 sepsis hospitalization.

	2009 (N = 15,836 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)	2010 (N = 17,021 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)	2011 (N = 16,844 readmissions) diagnosis category (proportion of readmissions that are for this diagnosis)
1	Congestive heart failure (7.0%)	Congestive heart failure (7.6%)	Congestive heart failure (7.4%)
2	Pneumonia (5.4%)	Pneumonia (5.3%)	Pneumonia (5.1%)
3	Sepsis (4.8%)	Sepsis (4.9%)	Sepsis (4.7%)
4	Urinary tract infection (4.6%)	Urinary tract infection (4.6%)	Urinary tract infection (4.5%)
5	Acute renal failure (4.3%)	Chronic obstructive pulmonary disease (4.1%)	Acute renal failure (4.4%)
6	Chronic obstructive pulmonary disease (3.9%)	Acute renal failure (4.0%)	Chronic obstructive pulmonary disease (4.0%)
7	Complication of device, implant, graft (2.8%)	Acute respiratory failure (2.7%)	Complication of surgical or medical care (2.8%)
8	Complication of surgical or medical care (2.7%)	Fluid/electrolyte disorder (2.7%)	Complication of device, implant or graft (2.7%)
9	Fluid/electrolyte disorder (2.6%)	Complication of device, implant or graft (2.4%)	Acute respiratory failure (2.6%)
10	Acute Respiratory Failure (2.5%)	Complication of Surgical or Medical Care (2.4%)	Fluid / Electrolyte Disorder (2.6%)

Figure 4. Top 10 readmission diagnoses after hospitalization for sepsis, by year of sepsis hospitalization. Readmission diagnoses are color-coded to facilitate easier comparison across the three subgroups. The top 10 diagnoses in 2009 were assigned a shade from *blue* to *green*, and these same color assignments were applied to 2010 and 2011. The same 10 diagnoses were the 10 most common readmissions diagnoses in 2009, 2010, and 2,011. The top four diagnoses also had the same rank each year.
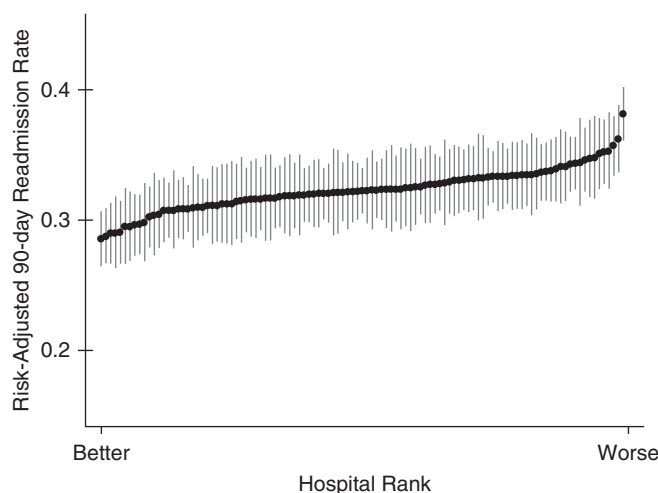
This study extends prior work examining the top readmission diagnoses after sepsis to a new population of patients and shows that, as a whole, veterans have similar postsepsis readmission patterns to Medicare beneficiaries. In both veterans and elderly Medicare beneficiaries, congestive heart failure, pneumonia, sepsis, urinary tract infection, respiratory failure, chronic obstructive pulmonary disease, acute renal failure, and complications of device, implant, or graft are important causes of hospital readmission after sepsis (4). The top two readmission diagnoses in veterans

surviving sepsis (heart failure and pneumonia) are also the top two causes of readmission after any medical hospitalization among fee-for-service Medicare beneficiaries (28).

Although the utility of hospital readmission as a performance measure is highly contested (29), hospital readmissions remain a substantial cost sink (30), with readmissions after sepsis being particularly expensive (9). Health care insurers such as Blue Cross/Blue Shield already use advanced risk prediction algorithms to identify patients at increased risk for all-

cause hospital readmissions and then offer these patients additional services in hopes of reducing their risk for a costly rehospitalization (31). Health management organizations such as Kaiser Permanente are working to embed tools into the electronic medical record to generate all-cause readmission risk predictions in real time (32). The VA currently generates weekly "Care Assessment Need" scores, each patient's percentile risk of hospitalization for any cause or death in the next 30, 60, 90, or 365 days, for the entire VA primary care population (33). To date, however, none of these tools has been proven to reduce the rate of rehospitalization.

The advances in real-time risk prediction are promising, but the potential benefit of such tools may be transformed by predicting a patient's risk for specific common and potentially preventable types of hospital readmission. Although the knowledge that a patient is at high risk for all-cause hospital readmission does not imply a specific course of action to a primary care physician charged with outpatient follow-up, knowledge that a patient is at high risk for infection provides more actionable information. Likewise, knowing a patient is high risk for acute renal failure or heart failure exacerbation suggests potential prevention strategies. This information could serve to focus time-pressured hospital follow-up visits, allowing clinicians to concentrate their history, physical exam, counseling, and medical decision making on addressing a patient's

Figure 5. Variation in risk-adjusted postsepsis readmission rate across VA hospitals. Hospitals are ranked by performance. Error bars from the hospital-level random effects are shown at 1.4 times the standard error, indicating that two hospitals with nonoverlapping error bars have significantly different rates of postsepsis readmission.

biggest and potentially modifiable medical risk factors for readmission.

Beyond providing guidance for individual clinicians, data on the most common readmission diagnoses may inform the planning of larger-scale interventions to reduce hospital readmissions or improve the quality of postdischarge care more generally. For example, although chronic nursing facility residents are likely the most frail subgroup examined, they also have the most concentrated collection of readmission diagnoses, such that close attention to a few select risk factors may provide absolute reductions in subsequent hospital use. In this subgroup, infection accounted for a quarter of all admissions, and aspiration pneumonitis for another 5%, both of which are amendable to prevention strategies (34, 35).

This study has some limitations. First, sepsis hospitalizations and readmission diagnoses were ascertained by ICD-9-CM codes, with the possibility for misclassification. Furthermore, because readmission diagnosis category was derived from just the principal hospitalization, secondary and multifactorial causes for readmission were not assessed. Second, although patterns of hospital readmission differ by prior and subsequent nursing facility use, it is impossible to ascertain the extent to which this variation is explained by differences in patient case-mix vs. the influence of nursing facilities. The study was not designed to test the role of patient vs. contextual factors on readmission patterns but, rather, to determine, conditional on being in a nursing facility after a sepsis hospitalization, what are the common readmission diagnoses.

Conclusions

Patterns of readmission after sepsis have little variation by admission year or hospital, but differ by patient age and nursing facility use, which has important implications for designing postdischarge interventions. Temporal stability but patient-level variation in readmission patterns suggest that cause-specific readmission risk prediction may be feasible. ∎

References

1 Torio CM, Andrews RM. National Inpatient Hospital Costs: The Most Expensive Conditions by Payer, 2011. HCUP Statistical Brief #160. Rockville, MD: Agency for Healthcare Research and Quality; 2013.

2 Iwashyna TJ, Cooke CR, Wunsch H, Kahn JM. Population burden of long-term survivorship after severe sepsis in older Americans. *J Am Geriatr Soc* 2012;60:1070–1077.

3 Prescott HC, Langa KM, Liu V, Escobar GJ, Iwashyna TJ. Increased 1-year healthcare use in survivors of severe sepsis. *Am J Respir Crit Care Med* 2014;190:62–69.

4 Prescott HC, Langa KM, Iwashyna TJ. Readmission diagnoses after hospitalization for severe sepsis and other acute medical conditions. *JAMA* 2015;313:1055–1057.

5 Goodwin AJ, Rice DA, Simpson KN, Ford DW. Frequency, cost, and risk factors of readmissions among severe sepsis survivors. *Crit Care Med* 2015;43:738–746.

6 Jones TK, Fuchs BD, Small DS, Halpern SD, Hanish A, Umscheid CA, Baillie CA, Kerlin MP, Gaieski DF, Mikkelsen ME. Post-acute care use and hospital readmission after sepsis. *Ann Am Thorac Soc* 2015;12:904–913.

7 Liu V, Lei X, Prescott HC, Kipnis P, Iwashyna TJ, Escobar GJ. Hospital readmission and healthcare utilization following sepsis in community settings. *J Hosp Med* 2014;9:502–507.

8 Donnelly JP, Hohmann SF, Wang HE. Unplanned readmissions after hospitalization for severe sepsis at academic medical center–affiliated hospitals. *Crit Care Med* 2015;43:1916–1927.

9 Chang DW, Tseng CH, Shapiro MF. Rehospitalizations following sepsis: common and costly. *Crit Care Med* 2015;43:2085–2093.

10 Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR. Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. *Crit Care Med* 2001;29:1303–1310.

11 Iwashyna TJ, Odden A, Rohde J, Bonham C, Kuhn L, Malani P, Chen L, Flanders S. Identifying patients with severe sepsis using administrative claims: patient-level validation of the angus implementation of the international consensus conference definition of severe sepsis. *Med Care* 2014;52:e39–e43.

12 Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, Bellomo R, Bernard GR, Chiche JD, Coopersmith CM, *et al*. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA* 2016;315:801–810.

13 Levy MM, Fink MP, Marshall JC, Abraham E, Angus D, Cook D, Cohen J, Opal SM, Vincent JL, Ramsay G; International Sepsis Definitions Conference. 2001 SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference. *Intensive Care Med* 2003;29:530–538.

14 Cooper AL, Jiang L, Yoon J, Charlton ME, Wilson IB, Mor V, Kizer KW, Trivedi AN. Dual-system use and intermediate health outcomes among veterans enrolled in Medicare Advantage plans. *Health Serv Res* 2015;50:1868–1890.

15 Borowsky SJ, Cowper DC. Dual use of VA and non-VA primary care. *J Gen Intern Med* 1999;14:274–280.

16 Shen Y, Hendricks A, Zhang S, Kazis LE. VHA enrollees' health care coverage and use of care. *Med Care Res Rev* 2003;60:253–267.

17 Healthcare Cost and Utilization Project. Clinical classifications software (CCS) for ICD-9-CM. Rockville, MD: Agency for Healthcare Research and Quality; 2014.

18 Agency for Healthcare Research and Quality. Guide to prevention quality indicators [updated 2007 Mar; accessed 2014 Sep 30]. Available from: http://www.qualityindicators.ahrq.gov/Downloads/Modules/PQI/V31/pqi_guide_v31.pdf

19 Prescott HC, Kepreos KM, Wiitala WL, Iwashyna TJ. Temporal changes in the influence of hospitals and regional healthcare networks on severe sepsis mortality. *Crit Care Med* 2015;43:1368–1374.

20 Render ML, Kim HM, Welsh DE, Timmons S, Johnston J, Hui S, Connors AF Jr, Wagner D, Daley J, Hofer TP; VA ICU Project (VIP) Investigators. Automated intensive care unit risk adjustment: results from a National Veterans Affairs study. *Crit Care Med* 2003;31:1638–1646.

21 Render ML, Deddens J, Freyberg R, Almenoff P, Connors AF Jr, Wagner D, Hofer TP. Veterans Affairs intensive care unit risk adjustment model: validation, updating, recalibration. *Crit Care Med* 2008;36:1031–1042.

22 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–383.

23 Klabunde CN, Potosky AL, Legler JM, Warren JL. Development of a comorbidity index using physician claims data. *J Clin Epidemiol* 2000;53:1258–1267.

24 Dimick JB, Welch HG, Birkmeyer JD. Surgical mortality as an indicator of hospital quality: the problem with small sample size. *JAMA* 2004;292:847–851.

25 Dimick JB, Staiger DO, Birkmeyer JD. Ranking hospitals on surgical mortality: the importance of reliability adjustment. *Health Serv Res* 2010;45:1614–1629.

26 Hofer TP, Hayward RA, Greenfield S, Wagner EH, Kaplan SH, Manning WG. The unreliability of individual physician "report cards" for assessing the costs and quality of care of a chronic disease. *JAMA* 1999;281: 2098–2105.

27 Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, Råstam L, Larsen K. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *J Epidemiol Community Health* 2006;60:290–297.

28 Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009; 360:1418–1428.

29 Axon RN, Williams MV. Hospital readmission as an accountability measure. *JAMA* 2011;305:504–505.

30 Hines AL, Barrett ML, Jiang HJ, Steiner CA. Agency for Healthcare Research and Quality Statistical Brief #172. Conditions with the largest number of adult hospital readmissions by payer, 2011. Rockville, MD: Agency for Healthcare Research and Quality; 2014 [accessed 2016 Feb 6]. Available from: http://www.hcup-us.ahrq. gov/reports/statbriefs/sb172-Conditions-Readmissions-Payer.pdf

31 Bookman T. Insurer uses personal data to predict who will get sick. Washington, DC: NPR; 2015 [accessed 2016 Feb 6]. Available from: http://www.npr.org/sections/health-shots/2015/06/08/408190121/ insurer-uses-personal-data-to-predict-who-will-get-sick

32 Escobar GJ, Ragins A, Scheirer P, Liu V, Robles J, Kipnis P. Nonelective rehospitalizations and postdischarge mortality: predictive models suitable for use in real time. *Med Care* 2015;53: 916–923.

33 Fihn SD, Francis J, Clancy C, Nielson C, Nelson K, Rumsfeld J, Cullen T, Bates J, Graham GL. Insights from advanced analytics at the Veterans Health Administration. *Health Aff (Millwood)* 2014;33: 1203–1211.

34 Mody L, Krein SL, Saint S, Min LC, Montoya A, Lansing B, McNamara SE, Symons K, Fisch J, Koo E, *et al*. A targeted infection prevention intervention in nursing home residents with indwelling devices: a randomized clinical trial. *JAMA Intern Med* 2015;175:714–723.

35 Liantonio J, Salzman B, Snydermand D. Preventing aspiration pneumonia by addressing three key risk factors: dysphagia, poor oral hygiene, and medication use. *Ann Longterm Care* 2014;22:42–48.