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SPECIAL ISSUE: LINKING VA AND NON-VA DATA TO ADDRESS US VETERAN HEALTH SERVICES ISSUES

The Impact of Healthcare-Associated Methicillin-Resistant *Staphylococcus aureus* Infections on Postdischarge Health Care Costs and Utilization across Multiple Health Care Systems

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Objective. To measure how much of the postdischarge cost and utilization attributable to methicillin-resistant *Staphylococcus aureus* (MRSA) health care-associated infections (HAIs) occur within the US Department of Veterans Affairs (VA) system and how much occurs outside.

Data Sources/Study Setting. Health care encounters from 3 different settings and payment models: (1) within the VA; (2) outside the VA but paid for by the VA (purchased care); and (3) outside the VA and paid for by Medicare.

Study Design. Historical cohort study using data from admissions to VA hospitals between 2007 and 2012.

Methods. We assessed the impact of a positive MRSA test result on costs and utilization during the 365 days following discharge using inverse probability of treatment weights to balance covariates.

Principal Findings. Among a cohort of 152,687 hospitalized Veterans, a positive MRSA test result was associated with an overall increase of 6.6 (95 percent CI: 5.7–7.5) inpatient days and \$9,237 (95 percent CI: \$8,211–\$10,262) during the postdischarge period. VA inpatient admissions, Medicare reimbursements, and purchased care payments accounted for 60.6 percent, 22.5 percent, and 16.9 percent of these inpatient costs.

Conclusions. While most of the excess postdischarge health care costs associated with MRSA HAIs occurred in the VA, non-VA costs make up an important subset of the overall burden.

Key Words. MRSA, healthcare-associated infection, healthcare utilization and cost

A number of recent efforts have been made to keep hospitalized patients safe from health care-associated infections (HAIs) in the United States. These include large-scale infection control efforts to prevent methicillin-resistant *Staphylococcus aureus* (MRSA) HAIs, such as one in the Department of Veterans Affairs (VA) health care system (Jain et al. 2011) as well as financial penalties and disincentives instituted by the Centers for Medicaid and Medicare Services (CMS) (Waters et al. 2015). While many studies have found that these efforts have been successful in reducing the incidence of HAIs, these events still represent one of the most common sources of preventable error among hospitalized patients (Zimlichman et al. 2013).

The VA health care system, the largest integrated health care system in the United States, provides care for 6 million Veterans per year in more than 150 hospitals and 1,000 outpatient clinics. While some Veterans receive care exclusively from VA facilities and providers, many Veterans have private or government insurance coverage that allows them to obtain health care services outside the VA. In addition, under certain circumstances, Veterans can receive health care services outside the VA that are paid for by the VA through a service called purchased care. The VA has offered this service to Veterans when it is infeasible for the VA to provide the care itself due to limited capacity, for example, or because of the urgent nature of the care needed. As barriers to receiving non-VA care continue to fall, it is increasingly important to understand the contribution of care from different sources on the overall economic burden of disease.

Most studies estimating the cost attributable to HAIs have been limited to costs that are incurred prior to patient discharge. However, even after discharge, an HAI may lead a patient to seek additional health care. For example, evidence suggests that patients with MRSA HAIs are at high risk for recurrent

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infections (Huang et al. 2011). In addition, *Staphylococcus aureus* infections may lead to long-term disabilities such as chronic ventilator dependence or end-stage renal disease (Su et al. 2013). We recently published a study estimating costs for the postdischarge period within the VA system for MRSA HAIs that occurred during a VA hospital stay (Nelson et al. 2015). To complement this previous analysis, and to provide a more complete estimate of the excess health care costs and resources used to care for patients with HAIs, our current study includes care obtained both within and outside the VA health care system for a subset of Veterans who were eligible for Medicare. Our goal was to examine how much of the postdischarge cost and utilization attributable to MRSA HAIs occur within the VA system and how much occurs outside. We performed these analyses using data from health care encounters that occurred in 3 different settings and payment models: (1) encounters that occurred within the VA and, therefore, utilized VA resources, (2) encounters that occurred outside the VA but were paid for by the VA through the purchased care program, and (3) encounters that occurred outside the VA and were paid for by Medicare.

METHODS

Study Design and Population

This was a historical cohort study of patients admitted to a VA hospital in the United States from October 1, 2007, through December 31, 2012. Patients were excluded from our analysis if their hospital stay was ≤ 2 days or > 90 days, died during the index hospitalization, had less than 365 days of observation time prior to admission, or had a positive clinical culture for MRSA prior to admission. The 365-daytime period prior to admission was used to identify baseline covariates. In addition, we further restricted our cohort to patients who were enrolled in Medicare. Finally, for patients that had multiple hospitalizations during the study period, we selected the first hospitalization event as the index date for subsequent observations.

Data

Pre-index Patient Demographic, Clinical Characteristics, and Health Care Utilization. We obtained patient demographic data and diagnosis codes as International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) from the VA corporate data warehouse (CDW), a repository for

electronic health care information. Encompassing both clinical and administrative data, this repository enables researchers to access a collection of data domains from VA facilities nationwide (Fihn et al. 2014). VA cost data were extracted from the VA Managerial Cost Accounting system, which is an activity-based accounting system within the VA. Using Medicare claims data obtained from the VA Information Resource Center (VIREC) (Hynes et al. 2007), we constructed Medicare cost and utilization outcomes from Medicare Provider and Analysis Review (MedPAR), outpatient, and carrier claims. Finally, purchased care data included the amount paid by the VA to non-VA providers for care received outside the VA.

Microbiology. The VA MRSA Prevention Initiative—consisting of universal nasal surveillance, contact precautions, and hand hygiene—was implemented in 2007 (Jain et al. 2011). This was a cultural shift of MRSA infection control onus to everyone with patient contact. Mandatory MRSA colonization screening upon admission, unit-to-unit transfer, and discharge from a VA facility was one facet of this program. MRSA screening results were entered into patients' electronic medical records as noncoded data and our team developed a natural language processing (NLP) tool that allowed extraction of cultured microorganisms, antibiotic susceptibilities, and classification of MRSA colonization from these records (Jones et al. 2012). This NLP tool was highly accurate with positive predictive value exceeding 97.9 percent for both organism and resistance.

Data Linkage. Our analysis required linking data from multiple VA, Medicare, and purchased care data files. The linking was done using scrambled Social Security number, which is a unique patient identifier that is present in each of these databases. We are not aware of any previous study that has estimated the health care costs in Medicare and VA purchased care associated with MRSA HAIs acquired in a VA hospital. This unique combination of microbiology, clinical, and cost data from VA and cost data from Medicare claims and purchased care billing data was possible because of a data sharing agreement between the VA (through VIREC) and the Centers for Medicare and Medicaid Services.

Outcomes

Our primary outcomes were inpatient costs and utilization for 12 months following hospital discharge. We estimated the impact of MRSA HAI on the 3

types of cost (VA, Medicare, and purchased care) separately and then summed the results in order to obtain an overall estimate. Confidence intervals for the summed results were constructed by calculating a pooled variance across the different components. We converted costs to 2016 US dollars using the Personal Consumption Expenditures price index constructed by the US Bureau of Economic Analysis (Dunn, Grosse, and Zuvekas 2018). In addition, we also examined postdischarge outpatient costs and utilization outcomes including the number of outpatient encounters and the number of inpatient days. Outpatient encounters were defined as the number of unique calendar days on which an outpatient visit occurred. In other words, if a Veteran had multiple clinic stops on one day, they were considered part of the same VA outpatient encounter. In order to focus on acute care readmissions during the follow-up period, we excluded VA inpatient stays of 90 days or longer and Medicare skilled nursing home admissions from our inpatient cost and utilization outcomes.

Independent Variables

The primary independent variable for our models was an incident positive MRSA test result following hospital admission. An individual can be colonized by MRSA, meaning that the bacteria are living on the skin, without being symptomatic. An infection, on the other hand, occurs when the bacteria have entered the body through an opening and is actively causing disease in the individual. Electronic microbiology reports in VA data consist of the results from culture tests in which an area of an individual's body is swabbed and tested for the presence of MRSA. The results from these tests may be positive or negative. A positive test indicates that MRSA is present but does not differentiate between colonization and infection. Those who tested negative for MRSA may still be positive for other organisms such as methicillin-sensitive *Staphylococcus aureus* or gram-negative bacteria.

In an effort to distinguish between true infections and mere colonizations, we used an algorithm to classify positive MRSA test results into one of these two categories. A positive MRSA test result was classified as an HAI if specimens were taken from a sterile site (e.g., blood, bone, or device) or if the patient had a record for an anti-MRSA antimicrobial 5 days before or after the positive MRSA test result (Branch-Elliman, Strymish, and Gupta 2014). Otherwise, the positive test result was considered a colonization. To qualify as an HAI according to the US Center for Disease Control's National Healthcare Safety Network's surveillance definition, infections must be diagnosed after the first 48 hours of a hospitalization (Horan, Andrus, and Dudeck 2008).

In order to isolate the effect of positive MRSA test results on cost and utilization, we controlled for patient demographics (age, race, marital status, insurance status, gender, an VA priority status), health care costs accumulated in the VA or through Medicare during the 365-day period prior to index hospital admission, primary diagnosis for index hospitalization, surgery within first 48 hours of admission, and combination of Charlson and Elixhauser comorbidity measures. Gagne et al. demonstrated that combining the Charlson and Elixhauser measures better predicts 1-year mortality than either scores individually (Gagne et al. 2011).

Statistical Analysis

Inverse Probability of Treatment Weighting. We used propensity scores to conduct inverse probability of treatment weighting (IPTW) to balance observed patient characteristics across patients with a negative MRSA test result and patients with positive MRSA test result (Austin 2011). The advantage of IPTW, which is one type of marginal structural model for the estimation of causal effects (Hernan, Brumback, and Robins 2000, 2002), over matching with the propensity score is that this approach retains data from all patients in our study while creating a pseudo-population to achieve covariate balance. We calculated the probability of having a positive MRSA test result with a multivariable logistic regression, which accounted for risk factors for postdischarge cost (Austin, Grootendorst, and Anderson 2007). To reduce the influence of outliers, we truncated our weights at the 5th and 95th percentile (Cole and Hernan 2008; Lee, Lessler, and Stuart 2011).

Postindex Cost and Utilization Regressions. To estimate the impact of a positive MRSA test result on postdischarge VA outpatient costs, we used a generalized linear model. However, because a substantial proportion of patients did not incur non-VA outpatient costs or VA or non-VA inpatient costs, we used 2-part regression to model these outcomes: (1) probability of incurring any costs versus none and (2) the continuous cost (conditional on nonzero costs) (Mihaylova et al. 2011; Deb and Norton 2018). Part 1 of the 2-part model was performed using logistic regression while part 2 used a generalized linear model. We determined gamma was the most fitting for the cost data distribution using the modified Park test (Park 1966). These 2-part models were conducted in Stata using the *twopm* command, and results are presented as marginal effects across both the 1st and 2nd parts rather than just the 2nd part of the model in order to make inferences across the entire cohort (Belotti et al.

2015). For utilization outcomes, we used a negative binomial regression (and zero-inflated negative binomial regression where appropriate) for the number of outpatient encounters and 2-part regressions with Poisson distribution for the number of inpatient days.

RESULTS

Patient Characteristics

Table 1 depicts the characteristics of the Veterans included in our cohort. A total of 152,687 patients met the inclusion criteria of whom, 3,436 had a positive MRSA test result. Patients with a positive MRSA test result compared to those without were slightly older (71.9 vs. 69.0), had higher outpatient costs during the year prior to hospital admission (\$11,604 vs. \$10,633), and longer average length of index hospital stay (16.7 days vs. 9.0 days).

Cost Outcomes

Unadjusted Costs and Utilization. Figure 1 shows the unadjusted mean inpatient and outpatient costs during the 12 months postdischarge period for VA care, non-VA care paid for by Medicare, and non-VA care paid for by the VA through purchased care. Patients with a positive MRSA test result had higher mean inpatient across all care locations. The largest difference was seen in VA care (\$23,132 vs. \$17,497). Outpatient costs, on the other hand, were almost identical for patients with and without a positive MRSA test result in the 3 care locations.

The unadjusted mean number of inpatient days and outpatient encounters per patient at 12 months postdischarge is shown in Figure 2. The mean number of inpatient days was higher for patients with a positive test result compared to those patients without in VA settings (10.4 vs. 8.0), from Medicare claims (3.7 vs. 2.3), and from purchased care data (6.1 vs. 3.2). Those with a positive MRSA test result had more outpatient encounters, on average, paid for by Medicare (7.0 vs. 4.7) and through purchased care (2.5 vs. 2.2) but fewer outpatient encounters in the VA (27.4 vs. 30.3) compared with those without a positive test result.

Adjusted Costs and Utilization. The regression results for cost outcomes are shown in Table 2. Patients with a positive MRSA test result had \$9,237 (95 percent CI = \$8,211–\$10,262) greater total inpatient costs than those without a

Table 1: Patient Characteristics For Cohort

	<i>No Positive MRSA Test Result</i>		<i>Positive MRSA Result</i>	
	<i>Mean/N</i>	<i>SD/%</i>	<i>Mean/N</i>	<i>SD/%</i>
Total (n)	149,251		3,436	
Age (mean)	69.0	12.1	71.9	11.4
Gender, %				
Female	5,411	3.6%	83	2.4%
Male	143,840	96.4%	3,353	97.6%
Race/Ethnicity, %				
White	107,589	72.1%	2,484	72.3%
Black	25,074	16.8%	607	17.7%
Asian	523	0.4%	4	0.1%
Native American	753	0.5%	16	0.5%
Hispanic	8,881	6.0%	142	4.1%
Unknown/Missing	6,431	4.3%	183	5.3%
Marital status				
Married	68,898	46.2%	1,589	46.2%
Never married	13,593	9.1%	301	8.8%
Divorced	40,448	27.1%	852	24.8%
Separated	5,201	3.5%	117	3.4%
Widowed	20,790	13.9%	568	16.5%
Unknown/Missing	321	0.2%	9	0.3%
Medicare eligibility (%)				
65+	100,778	67.5%	2,577	75.0%
<65 disabled	48,473	32.5%	859	25.0%
Surgery within 48 h of inpatient admission, %				
No	113,853	76.3%	2,465	71.7%
Yes	35,398	23.7%	971	28.3%
CCI/Elixhauser, mean	1.6	2.4	1.8	2.6
Outpatient cost in 365 days	\$10,633	\$11,254	\$11,604	\$13,177
Length of stay during index hospitalization, mean	9.0	10.2	16.7	17.2

positive test result. More than half of these costs (60.6 percent) came from admissions to VA hospitals while 22.5 percent came from Medicare claims, and 16.9 percent were due to purchased care admissions. The magnitude of this increase in overall inpatient costs was higher for those whose positive test result was an infection (\$16,111; 95 percent CI = 13,119–\$19,103) versus those with a colonization (\$7,217; 95 percent CI = 6,432–\$8,002). The increase in postdischarge inpatient costs for MRSA HAIs ranged was \$8,302 (95 percent CI = \$3,870–\$12,733) for VA costs, \$4,985 (95 percent CI = \$3,300–\$6,670) for Medicare costs and \$2,824 (95 percent CI = \$733–\$4,916) for purchased care costs.

Overall, having a positive MRSA test result was associated with \$1,087 (95 percent CI = \$404–\$1,770) greater outpatient costs, with Medicare

Table 2: Impact of Positive MRSA Test Result on VA, Medicare, and Purchased Care Cost Outcomes During 365-day Postdischarge Period ($n = 152,687$)

MRSA Exposure	VA			Medicare			Purchased Care			Total		
	95%			95% CI			95% CI			95% CI		
	Effect	Lower	Upper	Effect	Lower	Upper	Effect	Lower	Upper	Effect	Lower	Upper
<i>Positive MRSA test result versus no positive MRSA test result</i>												
Outpatient costs	\$457	-\$702	\$1,616	\$636	\$430	\$842	-\$6	-\$121	\$109	\$1,087	\$404	\$1,770
Inpatient costs	\$5,593	\$4,095	\$7,090	\$2,082	\$1,391	\$2,773	\$1,561	\$901	\$2,222	\$9,237	\$8,211	\$10,262
<i>MRSA colonization versus no positive MRSA test result</i>												
Outpatient costs	\$431	-\$734	\$1,596	\$455	\$304	\$606	-\$6	-\$124	\$113	\$880	\$198	\$1,562
Inpatient costs	\$4,810	\$3,576	\$6,045	\$1,343	\$897	\$1,788	\$1,064	\$707	\$1,422	\$7,217	\$6,432	\$8,002
<i>MRSA HAI versus no positive MRSA test result</i>												
Outpatient costs	\$817	-\$4,454	\$6,087	\$1,560	\$995	\$2,125	\$2	-\$543	\$547	\$2,378	-\$698	\$5,455
Inpatient costs	\$8,302	\$3,870	\$12,733	\$4,985	\$3,300	\$6,670	\$2,824	\$733	\$4,916	\$16,111	\$13,119	\$19,103

Notes: Results presented are marginal effects from generalized linear models or two-part models. For each model, no MRSA positive test result is the reference group. Models adjusted for demographic characteristics, primary diagnosis for index hospitalization, surgery during index hospitalization, length of stay during index hospitalization, and health care cost in the 365 days prior to admission.

outpatient costs being the largest contributor (\$636, 95 percent CI = \$430–\$842). These results were consistent when positive MRSA test results were further categorized as colonizations and infections; however, the magnitude of these effects was largest for infections.

Table 3 shows the regression results for the utilization outcomes. While a positive MRSA test result was associated with fewer VA (−2.8; 95 percent CI: −3.6 to −2.0) outpatient encounters, it was associated with an increase in Medicare (2.0; 95 percent CI: 1.5–2.5) and purchased care (0.2; 95 percent CI: 0.1–0.4) outpatient encounters. The number of postdischarge inpatient days, however, increased with a positive MRSA test result across all settings with the effect ranging from 1.3 (95 percent CI: 0.9–1.8) for Medicare to 2.4 (95 percent CI: 1.7–3.1) for VA. As was the case with the cost outcome, the magnitude of effect was largest for the inpatient days outcome in patients with MRSA infections (9.4 (95 percent CI: 7.2–11.5) inpatient days across all settings) compared to patients with MRSA colonization (5.1 (95 percent CI: 4.5–5.7) inpatient days across all settings).

Tables S1 and S2 show the results for cost and utilization regressions, respectively, stratified by age. Overall inpatient cost estimates were highest for Medicare beneficiaries in our cohort under 65 years of age with \$13,292 (95 percent CI: \$10,470–\$16,115) for patients with a positive MRSA test result compared to those without a positive MRSA test result. Those 65 years and older with a positive MRSA test result incurred \$7,393 (95 percent CI: \$6,267–\$8,519) higher inpatient costs compared to those without a positive test result. In addition, a positive MRSA test result was associated with 5.3 (95 percent CI: 4.3–6.3) additional inpatient days for those over 65 years of age and older and 10.6 (95 percent CI: 8.4–12.8) additional inpatient days for those under 65 years. Finally, relative to no positive MRSA test result, an MRSA HAI was associated with 6.7 (95 percent CI: 3.8–9.6) fewer outpatient encounters for those 65 years and older but 4.7 (95 percent CI: 0.6–8.8) more outpatient encounters for those under age 65.

DISCUSSION

This study is the first to describe care received in multiple settings following discharge from an inpatient admission during which the patient acquired an MRSA infection. We did this by performing IPTW analyses comparing postdischarge cost and utilization between patients with and without an MRSA infection during an initial hospitalization. Our analysis contributes to

Table 3: Impact of MRSA Culture on VA, Medicare, and Purchased Care Utilization Outcomes During 365-day Postdischarge Period (*n* = 152,687)

MRSA Exposure	VA			Medicare			Purchased Care			Total		
	95% CI			95% CI			95% CI			95% CI		
	Effect	Lower	Upper	Effect	Lower	Upper	Effect	Lower	Upper	Effect	Lower	Upper
<i>Positive MRSA test result versus no positive MRSA test result</i>												
Outpatient encounters	-2.8	-3.6	-2.0	2.0	1.5	2.5	0.2	0.1	0.4	-0.6	-1.1	0.0
Inpatient days	2.4	1.7	3.1	1.3	0.9	1.8	2.9	1.5	4.3	6.6	5.7	7.5
<i>MRSA colonization versus no positive MRSA test result</i>												
Outpatient encounters	-2.8	-3.7	-2.0	1.5	1.2	1.9	0.3	0.1	0.4	-1.0	-1.6	-0.5
Inpatient days	2.1	1.5	2.6	1.0	0.7	1.3	2.1	1.3	2.8	5.1	4.5	5.7
<i>MRSA HAI versus no positive MRSA test result</i>												
Outpatient encounters	-5.1	-9.1	-1.1	3.8	2.2	5.3	-0.3	-1.1	0.5	-1.6	-4.1	0.9
Inpatient days	3.8	1.6	6.0	2.6	1.6	3.5	3.0	0.1	5.9	9.4	7.2	11.5

Notes: Results presented are marginal effects from generalized linear models or two-part models. For each model, no MRSA positive test result is the reference group. Models were weighted using inverse probability of treatment weights constructed from propensity scores estimated using the following independent variables: demographic characteristics, primary diagnosis for index hospitalization, surgery during index hospitalization, length of stay during index hospitalization, and health care cost in the 365 days prior to admission.

Figure 1: Unadjusted Mean Costs During 365 Days Following Discharge

Figure 2: Unadjusted Mean Utilization During 365 Days Following Discharge

a richer understanding of the estimated impact of MRSA HAI on post-discharge health care cost and utilization in a nationwide cohort of Veterans. We found that these infections were associated with higher overall inpatient costs during this follow-up period and that roughly 40 percent of these costs occurred in non-VA hospitals. For outpatient costs, the proportion of costs incurred outside the VA system was even higher (nearly 60 percent). This means that estimates of the postdischarge burden that only focus on the setting in which the initial hospitalization occurred may substantially underestimate the economic burden of HAIs.

It is important to note that the VA costs described here are those associated with providing care while the Medicare and purchased care costs are payments made to reimburse providers for care. These payment amounts are set based on negotiations between the payers (Medicare and the VA) and the entities providing the care and may not reflect the true costs of care. However, all 3 types of cost are incurred by the US federal government so, while the types of cost may differ, the payer is ultimately the same. Therefore, we feel that this exercise of combining these types of costs and describing the proportion incurred by each is appropriate. Even with these additions to the tally of the postdischarge costs of MRSA infections, more remain uncounted and should be the subject of future studies. These include direct medical costs for postdischarge health care encounters paid for by Medicaid and private health insurance as well as the productivity costs of missed work for additional outpatient encounters and inpatient stays for both patients and their caregivers.

Aside from filling in an important gap in the estimates of the excess cost of MRSA HAIs, this study also identifies an interesting pattern of the use of multiple health care systems. Our estimates suggest that there was an elevated risk of readmission to a non-VA facility paid for through Medicare or purchased care in the 365 days following an admission to a VA facility in which an MRSA HAI occurred. Readmissions are costly in general but when they occur at different hospitals than the initial admission, which may be the case for many of the readmissions in this study, care coordination can be difficult. A recent study identified an increased risk of mortality in patients readmitted to a different facility following discharge from a surgical admission (Brooke et al. 2015). Future studies should seek to understand whether poor outcomes are also associated with the non-VA readmissions identified here.

Our results are important because they suggest that cost of illness studies that only examine cost and utilization within one health care system may paint a limited picture of the overall burden on the patient and the health care community of that particular condition. As a result of this underestimation of the cost of HAIs specifically, economic evaluations of interventions to prevent these infections during a hospitalization that do not include postdischarge costs incurred outside of the health care system in which the HAI occurred may lead to flawed results. In other words, this study demonstrates the value of linking VA, Medicare, and purchased care data to conduct a cost of illness study. Having a more complete picture of the health care cost and utilization following an inpatient stay will lead to better evaluations of strategies to improve patient safety, ultimately leading to better patient outcomes through optimal clinical practice. For example, a recently published study examined

the cost-effectiveness and budget impact of the VA MRSA Prevention Initiative.(Nelson et al. 2016) This study compared the cost of the initiative to the cost of treating MRSA HAIs which would be avoided if the infections were prevented due to this intervention. Our estimates of the VA and non-VA postdischarge costs across associated with MRSA HAIs presented here could provide enhanced estimates of the treatment cost of MRSA HAIs for future economic evaluations of interventions to prevent these infections. In addition, while the results shown here are specific to the issue of MRSA HAI, similar distributions of postdischarge cost and utilization across VA and non-VA settings may exist for other hospitalized patients. Future estimates of the postdischarge costs associated with other preventable hospital-acquired events such as venous thromboembolism, falls, or pressure ulcers.

Improved estimates of the cost of MRSA HAIs can play a vital role in current policy decisions. A recent debate in the infection control community centers around the value of contact precautions (CPs), the use of gloves and gowns by providers when caring for patients in a health care facility to prevent transmission of infectious organisms. While CPs are recommended by the Centers for Disease Control and Prevention when caring for patients infected with certain multidrug-resistant organisms (Siegel et al. 2007), those calling for an end to CPs cite their low adherence and high cost while questioning their efficacy in preventing transmission (Morgan, Wenzel, and Bearman 2017). Others, however, caution that premature discontinuation of CPs may lead to an increase in infections (Rubin, Samore, and Harris 2018). Comprehensive estimates of the attributable cost of MRSA HAIs, including costs incurred following discharge across a variety of settings as presented in this study, would be an important component to an economic evaluation to determine the optimal setting for different CP strategies.

Our results are consistent with previous studies that have examined the postdischarge impact of HAIs. For instance, Emerson et al. (2012) found an elevated risk of readmission for HAIs due to MRSA, *Clostridium difficile* or vancomycin-resistant *Enterococci* (VRE) compared to patients with no infection (Emerson et al. 2012). In addition, our previous analysis, which did not include Medicare or purchased care data, showed significantly higher VA inpatient costs associated with MRSA HAIs (Nelson et al. 2015). In extending our previous analysis, the addition of non-VA data to the analysis of postdischarge cost and utilization associated with MRSA HAIs is an important one. First of all, these additional data sources account for more than one-third of the total cost burden of MRSA HAIs which means that previous estimates of the attributable postdischarge cost of these infections have been

underestimated. In addition, the proportion of burden for these infections that occurs outside the VA is likely even higher as we were not able to include costs from private insurance or other government payers such as Medicaid. And second, a better understanding of the health care utilization patterns for hospitalized patients can provide insight into the coordination of care across different providers as well as different health care systems.

By stratifying our analyses by age among Medicare beneficiaries, we found a negative association between MRSA HAI and overall outpatient encounters for those eligible for Medicare due to advanced age but a positive association in this relationship for those eligible for Medicare due to disability. This difference in outpatient utilization patterns is consistent with previous research using Medicare data which showed that disability-eligible Veterans had more VA primary care and specialty care outpatient visits than age-eligible Veterans (Liu et al. 2012). These results, which suggest that Veterans eligible for Medicare due to disability have greater outpatient health care needs than those eligible due to age, are important for both the VA and Medicare for resource allocation decisions as returning Veterans from recent military service in Iraq and Afghanistan may have greater health care needs than those from previous conflicts (Gawande 2004; Okie 2005).

We found that having a positive MRSA test result was associated with an increase in Medicare and purchased care outpatient encounters in the 365-day postdischarge follow-up period. While further analyses are necessary to better understand the reasons for increases in non-VA outpatient encounters and decreases in VA outpatient encounters, possible explanations include factors that have been identified as predictive of low reliance on VA outpatient care relative to Medicare (Liu et al. 2011). It may be that these factors—which include longer distance to VA facilities, more nonfederal primary care physicians in the county of residence, and Medicaid coverage—are more common in patients with positive MRSA test results than those without.

Our study had several limitations. First of all, our analyses were limited to only 2 payers for non-VA services: the VA through purchased care and Medicare. Many Veterans use non-VA services that are paid for through private insurance, representing additional costs not taken into account here. Veterans with the highest income and most likely to have employer-based insurance coverage are those in priority groups 7 and 8. In additional sensitivity analyses (results available upon request), results from our analyses were similar after excluding Veterans in these priority groups. Future research on the postdischarge costs of MRSA HAIs which include data from private insurance claims may pay particular attention to this subset of Veterans. Second,

our estimates of attributable cost may be biased due to unmeasured confounding. For example, patients who had invasive procedures during their stay or with multiple comorbidities are at higher risk for MRSA HAIs and are likely to have high postdischarge health care costs. While we took measures to minimize this bias by constructing treatment weights based on a propensity score for patients with and without a positive MRSA test result, some residual confounding likely remained. Third, our exposure of interest was a positive MRSA test result. While these test results may not all represent true infections, we used a published electronic algorithm to further classify these test results as infections based on the site from which the specimen was taken and whether an anti-MRSA antibiotic was administered. Positive test results from sterile sites and those that are treated are much more likely to be infections. It is important to remember, however, that positive test results that do not meet the criteria for infection defined by this algorithm may still represent infections. In other words, the algorithm does not have perfect discrimination between colonizations and infections. Lastly, our cohort of patients may not be representative of the US population. The VA population has a higher proportion of elderly males with multiple comorbidities, which may limit the generalizability of our results.

In conclusion, we estimated the attributable postdischarge outpatient and inpatient health care costs and utilization associated with an MRSA HAI across multiple systems and payers. We found that 60 percent of the inpatient costs and 40 percent of the outpatient costs are incurred in VA facilities. These costs contribute to the overall burden of such infections beyond previous estimates involving VA resources.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix SA1: Author Matrix.

Figure S1: Cohort Selection Diagram.

Table S1: Impact of MRSA Culture on VA, Medicare, and Purchased Care Cost Outcomes During 365-day Post-Discharge Period.

Table S2: Impact of MRSA Culture on VA, Medicare, and Purchased Care Utilization Outcomes During 365-day Post-Discharge Period.