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Substantial Shifts in Ranking of California Hospitals by Hospital- Associated Methicillin-Resistant *Staphylococcus aureus* Infection Following Adjustment for Hospital Characteristics and Case Mix

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BACKGROUND. States have established public reporting of hospital-associated (HA) infections—including those of methicillin-resistant *Staphylococcus aureus* (MRSA)—but do not account for hospital case mix or postdischarge events.

OBJECTIVE. Identify facility-level characteristics associated with HA-MRSA infection admissions and create adjusted hospital rankings.

METHODS. A retrospective cohort study of 2009-2010 California acute care hospitals. We defined HA-MRSA admissions as involving MRSA pneumonia or septicemia events arising during hospitalization or within 30 days after discharge. We used mandatory hospitalization and US Census data sets to generate hospital population characteristics by summarizing across admissions. Facility-level factors associated with hospitals' proportions of HA-MRSA infection admissions were identified using generalized linear models. Using state methodology, hospitals were categorized into 3 tiers of HA-MRSA infection prevention performance, using raw and adjusted values.

RESULTS. Among 323 hospitals, a median of 16 HA-MRSA infections (range, 0-102) per 10,000 admissions was found. Hospitals serving a greater proportion of patients who had serious comorbidities, were from low-education zip codes, and were discharged to locations other than home were associated with higher HA-MRSA infection risk. Total concordance between all raw and adjusted hospital rankings was 0.45 (95% confidence interval, 0.40-0.51). Among 53 community hospitals in the poor-performance category, more than 20% moved into the average-performance category after adjustment. Similarly, among 71 hospitals in the superior-performance category, half moved into the average-performance category after adjustment.

CONCLUSIONS. When adjusting for nonmodifiable facility characteristics and case mix, hospital rankings based on HA-MRSA infections substantially changed. Quality indicators for hospitals require adequate adjustment for patient population characteristics for valid interhospital performance comparisons.

Methicillin-resistant *Staphylococcus aureus* (MRSA) is the most common cause of hospital-associated (HA) infections in the United States, accounting for approximately 300,000 hospitalizations and 19,000 deaths each year.[1-3] Additionally, the risk of MRSA infection persists during the immediate postdischarge period. Serious MRSA infections are present in 20%-30% of patients per year of carriage, incurring attributable mortality in high-risk patients.[4]

The growing burden of MRSA has drawn widespread attention from state legislatures and national agencies. As of 2013, the Centers for Medicare and Medicaid has added MRSA bloodstream infection measures to its Hospital Inpatient Quality Reporting Program.[5] Additionally, in 2009, California mandated public reporting of healthcare-associated MRSA blood- stream infection rates. Such initiatives assume that reported rates should be used for hospital comparison. However, these rates do not include the large portion of HA infections occurring in the immediate postdischarge period.6 Arguably, 30- day readmissions associated with MRSA infection should be included in this assessment. Additionally, these publicly re- ported rates are not adjusted for hospital-level factors or case mix, which may influence the risk of MRSA infection. While a great deal of research has focused on describing patient-level risk factors for MRSA infection,7-9 there is a gap in knowledge of facility-level predictors of hospital MRSA infections rates.

We sought to identify facility-level factors associated with higher rates of HA-MRSA pneumonia and sepsis infections across California hospitals to improve hospital comparisons.

METHODS

Data Sources and Evaluation of Hospital Characteristics

We conducted a retrospective cohort study of all licensed acute care hospitals in California to evaluate facility-level predictors of HA-MRSA pneumonia and sepsis infections be- tween January 1, 2009, and December 31, 2010, using state mandatory hospitalization data.[10] These data contain line item admission details, including demographic and *International Classification of Diseases, Ninth Revision* (ICD-9) diagnostic and procedure data from all California hospitals. Each diagnostic ICD-9 code is associated with a present on ad- mission (POA) code to indicate whether a given condition existed at the time of admission (POA p yes) or was acquired during the hospital stay (POA p no). Prior research has shown that the POA indicator, as reported through California hospital discharge data, is an accurate indicator for designating conditions as POA.[11,12] Psychiatric, chemical dependency, and low-volume (fewer than 1,000 admissions) hospitals were excluded, as were long-term acute care centers, as defined by a mean length of stay of 25 days or more.

We additionally used the US Census American Community Survey (2006-2010 and 2010) to characterize communities from which patients were admitted based upon patient zip code.[13] Census tract-level data were aggregated to zip code level for select socioeconomic and household variables previously associated with MRSA infection or poor health.[14,15] Last, hospital type (major teaching, community, pediatric) was obtained from publicly available data from the California Department of Public Health.[16] Major teaching hospitals were defined as those affiliated with a school of medicine and having multiple clinical services through which medical students and residents rotate. Community hospitals were defined as those not classified as teaching hospitals or stand-alone pediatric hospitals. This study was approved by the institutional review board of the University of California regents.

Hospital characteristics were generated by summarizing variables across all 2009 and 2010 annual admissions in multiple domains. We evaluated the proportion of admitted patients by age, sex, race, ethnicity, insurance (commercial, Medicare, and Medicaid), hospital admission/discharge lo- cation, comorbidities, surgery during that admission, and length of stay. The proportion of admitted patients with select comorbidities was assessed using the individual components of the Elixhauser criteria aggregated at the hospital level.[17,18] Hospitals were further characterized by the number of li- censed beds, annual admissions, and hospital type.

Last, census tract-level data were aggregated to the zip code level using American Community Survey variables for education, poverty, income, overcrowding, and unemployment.[19] Patients were assigned the characteristic of their home zip code. Zip codes were described by levels of unemployment (percent unemployed males), crowding (percent occupied housing units with more than 1 person per room), poverty (percent living below the federal poverty level), education (percent of adults 25 year and older with less than a high school education), and income (percent of households receiving interest, dividend, or net rental income) of their res- idents. Census characteristics from admitted patients with zip codes outside of California (less than 2% of all admissions) were excluded. Hospitals were described by the mean values across home zip codes of admitted patients when creating socioeconomic status variables.

Invasive HA-MRSA Infection

Using the California mandatory discharge data set, we evaluated the use of ICD-9 codes for MRSA septicemia (038.12) and MRSA pneumonia (482.42) infections in any diagnosis position for admitted California inpatients during 2009–2010. Using a patient unique identifier (record linking numbers), we tracked patients across CA hospital admissions to categorize MRSA infections as (1) predischarge-detected HA- MRSA infection, MRSA infection with POA p no (indicating a clear hospital failure in preventing an infection); or (2) postdischarge-detected HA-MRSA infection, MRSA infection with POA p yes and within 30 day of a previous hospitalization that did not have an MRSA infection. If a patient had multiple hospitalizations within the previous 30 days, the hospital with the most recent admission was indicated as having a postdischarge-detected HA-MRSA infection event. A 30-day time frame was selected to increase the accuracy of attributing postdischarge-detected events to the recent hos- pitalization.6,20 Additionally, similar to prior studies,6,20 we evaluated the cumulative proportion of postdischarge-detected MRSA infections captured within 90 and 365 days after hospital of index discharge as previous studies have reported serious infections among carriers in the year following dis- charge.4 Patients with HA-MRSA infections in sequential ad- missions were counted only once. Postdischarge detected refers to the 30-day time interval, unless otherwise specified. Last, we identified the capture of postdischarge-detected MRSA infections by sequential ICD-9 coding position after the principal diagnosis. For each hospital, we calculated HA- MRSA infection rates as the proportion of pre- or postdischarge-detected HA-MRSA infection cases out of total admissions.

Statistical Analysis

For all hospitals, we reported the median and interquartile range for aggregated hospital characteristics. To evaluate hospital-level predictors of MRSA infection rates, a generalized linear regression model was estimated to quantify the association between continuous hospital characteristics and the mean rate of HA-MRSA infections. The negative binomial family was used for the distribution of the number of infections to adjust for the overdispersion in the data relative to the Poisson family. Characteristics significant at $P < .1$ were entered into a multivariable Poisson regression model and retained at $P < .20$. For retained facility-level factors, increases in the proportion of admissions with an HA-MRSA infection were modeled per 10% increase in respective facility-level factors. Additional sensitivity analyses were conducted to evaluate facility predictors associated with HA-MRSA infections when using 90 and 365 days postdischarge-detected HA-MRSA infections. The final model was equivalent to a Poisson-gamma hierarchical generalized linear model.21 Using significant facility-level predictors for HA-MRSA infections, we then fit the hierarchical model with saturated random effects in order to use the estimated random effects as the basis for creating an adjusted hospital ranking system.21,22 Adjusted performance is the product of 2 terms from the model: (1) a fixed effect based on the mean performance as expected of a hospital with a given case mix; and (2) a random effect for the particular hospital, which adjusts for the relative performance of that hospital with respect to expectation. The hospitals were then ranked on the basis of their estimated adjustment factor, and we used Kendall's t concordance statistic to compare raw with adjusted rankings.23

Additionally, since public reporting methodology from multiple states often lists hospitals in healthcare performance categories,24-26 we used hospitals' raw and adjusted proportions of HA-MRSA infection admissions to separately categorize hospitals into performance categories, using the California Department of Public Health's methodology.25 This involves the creation of an exact Poisson 95% confidence interval (CI) based on hospitals' proportions of HA-MRSA infections. Hospitals as stratified by community and teaching affiliation were placed into poor, average, and superior performance categories if the state's mean proportion was above, within, or below a hospital's 95% CI, respectively. The methodology was applied to both the hospitals' observed (raw) and adjusted predicted performance, where the adjusted performance is estimated by the hospital-level predicted values from the hierarchical regression model. We then assessed agreement between raw and adjusted performance category using Cohen's (weighted) k. All analyses were performed in SAS (ver. 9.3; SAS Institute) and R (ver. 3.0).

RESULTS

Hospital Characteristics

Table 1 shows median and interquartile range values for hospital-level characteristics aggregated from 5,530,181 hospitalizations in 323 California hospitals. Twenty (6.2%) were teaching hospitals. Hospital case mix varied substantially, with the proportion of patients with diabetes ranging from 0.6% to 30.7% and with renal failure from 0% to 28.8%.

HA-MRSA Infections

Across the 2-year period, there were 6.5 predischarge-detected HA-MRSA infections per 10,000 admissions (*N* p 3,475). An additional 11.6 HA-MRSA infections per 10,000 admissions (*N* p 6,225) were identified within 30 days after dis- charge, leading to a total event risk of 18.0 per 10,000 admissions. Cumulative capture was 39.8% (*N* p 2,479) at 7 days, 63.7% (*N* p 3,965) at 14 days, and 82.4% (*N* p 5,126) at 21 days. Among 30-day postdischarge-detected HA-MRSA infections, 79% of cases were coded within the first 3 ICD- 9 positions for the readmitted hospital stay. When evaluating events within 31–365 days after discharge, an additional 6,226 events were detected.

Facility-Level Predictors

Facility-level factors associated with the mean HA-MRSA pneumonia and sepsis infections are shown in Table 2. For every 10% increase in a hospital's percent of diabetic patients, there was a 1.39-fold increase (95% CI, 1.22–1.59) in the proportion of a hospital's HA-MRSA infection admissions. Other facility factors significantly associated with the pro- portion of HA-MRSA infection admissions included hospital's mean length of stay as well as a higher proportion of admitted patients with renal failure, acquired immunodeficiency syndrome, and fluid/electrolyte abnormalities. In contrast, a hospital with a higher proportion of admissions being discharged to home or with a higher proportion of male admissions were associated with a significantly lower proportion of admissions with HA-MRSA infections.

Among socioeconomic variables, an increase of 10% in patients admitted from home zip codes with low education was associated with a 9% (95% CI, 1.01–1.17) increase in a hospital's proportion of HA-MRSA infection admissions. Zip codes with a high proportion of persons living below the federal poverty level were collinear with this education variable in the multivariate model.

Multivariate analysis of HA-MRSA infection outcomes including an extended postdischarge detection of 90 days and 365 days showed that the same facility-level predictors were significant.

Comparison of Adjusted Hospital Rankings to Raw Rankings

When evaluating hospital rankings as a continuous measure, raw rankings had only a 0.45 concordance (95% CI, 0.40– 0.51) with adjusted rankings on the basis of the above models. Among all possible pairs of ranked hospitals, the relative ranking of 1 hospital to the other reversed in 28% of pairs when adjusted rather than the raw rankings were used. An improvement in the adjusted rank of a hospital was attributed to its superior performance relative to the performance expected of an average hospital with the same case load. This is further illustrated as a graphical representation of general agreement between community and teaching hospitals' raw and adjusted HA-MRSA rates (Figure 1).

When using a 3-tier performance metric to compare raw versus adjusted rankings, a k of 0.66 was found between com- munity hospital performance categories. For community hospitals, this amounted to 20.3% of hospitals changing a performance category. Among the 71 community hospitals in the superior-performance category, 49.3% (*N* p 35) moved into the average-performance category after adjustment (Table 3). Among 53 community hospital in the poor-performance HA-MRSA infection prevention category, nearly 22.6% (*N* p 12) moved into the average-performance category. Additionally, among the 172 community hospitals in the average-performance category, 7.6% (*N* p 13) moved into either the poor or the superior categories.

For teaching hospitals, a k of 0.86 was found between raw and adjusted rankings using the 3-tier performance metric. After adjusting for facility-level predictors of HA-MRSA infection admissions, 2 of 20 teaching hospitals changed to a different category of performance (Table 3; Figure 1B).

TABLE 1. Inpatient Characteristics of 323 California Hospitals, 2009–2010

Characteristic	Median, %	Interquartile range
Sex, male	38.6	36.1–43.2
Age, years		
<18	2.5	0.9–5.5
18–44	27.7	21.0–33.1
45–54	11.9	10.6–14.1
55–64	14.2	12.5–16.7
65–74	14.9	13.1–16.8
75–84	15.6	12.7–18.6
≥85	10.4	7.4–14.2
Length of stay, days		
1–2	20.8	18.2–24.9
3–4	41.8	38.2–45.1
≥5	36.3	32.2–41.6
Race		
White	75.8	53.3–88.8
Black	0.2	0.1–0.5
Asian	4.6	1.8–10.6
Other	15.9	7.1–31.1
Hispanic	18.9	10.0–33.1
Census aggregated variables from California zip codes		
Adults ≥25 years with less than high school education	19.1	13.7–25.9
Unemployed males	6.6	5.7–7.4
Occupied housing units with more than 1 person per room	7.1	4.9–11.2
People living below federal poverty level	13.4	10.5–16.9
Housing receiving interest, dividend, or net rental income	22.7	17.0–28.1
Select comorbidities		
Congestive heart failure	7.7	6.0–9.6
Diabetes without chronic complications	16.6	13.5–20.4
Renal failure	10.8	7.8–14.3
Liver disease	3.1	2.5–4.0
Acquired immunodeficiency syndrome	0.1	0.0–0.2
Metastatic cancer	1.8	1.2–2.4
Solid tumor without metastasis	1.7	1.4–2.1
Fluid and electrolyte disorders	19.3	15.6–25.0
Recent surgery	29.0	22.6–34.2
Insurance type		
Medicare	43.7	35.8–51.0
Medicaid	18.8	9.1–29.3
Commercial	25.3	17.1–38.4
Location before admission		
Home	91.4	86.6–94.8
Acute inpatient care	1.0	0.3–2.3
Skilled nursing	2.6	1.1–4.8
Location after discharge		
Home	69.6	63.0–75.4
Acute care	2.4	1.3–3.7
Skilled nursing	9.6	6.1–13.2
Home health	0.5	0.1–1.0
Died	2.4	1.8–2.8

TABLE 2. Estimated Mean Model for Facility-Level Predictors Associated with Hospital-Associated Methicillin-Resistant *Staphylococcus aureus* (HA-MRSA) Infections

Characteristic	Estimate (β)	95% CI	P
Diabetes	1.39	1.22–1.59	<.0001
Renal failure	1.19	1.05–1.36	<.01
Fluid and electrolyte disorders	1.15	1.05–1.26	<.01
Acquired immunodeficiency syndrome	5.55	1.15–26.9	.03
Admitted from low-education zip code	1.09	1.01–1.17	.03
Mean length of stay	1.09	1.05–1.15	<.001
Admission from home	1.06	0.99–1.14	<.1
Discharged to home	0.88	0.81–0.95	<.001
Sex, male	0.91	0.84–0.99	<.05

NOTE. Psychiatric, chemical dependency, and low-volume (fewer than 1,000 admissions) hospitals were excluded, as were long-term acute care centers, as defined by mean length of stay of 25 days or more. Per 10% increase in a hospital's admissions involving patients with respective characteristics, there is an associated β-fold multiplicative increase or decrease in a hospital's proportion of HA-MRSA infection admissions. Model also adjusted for preadmission location. CI, confidence interval.

DISCUSSION

Benchmarking through public reporting is aimed at enabling patients to identify quality providers and motivate providers to identify areas of poor performance for improvement.[27-29] In the case of HA-MRSA infection reporting, hospital comparisons are meant to address best performance and process measures for meeting infection prevention standards. Thus, hospital rankings and performance categorization should not suffer simply because of the patient population they serve. Providing adjusted rankings that account for known non- modifiable risk factors for these outcomes enables accurate and fair comparisons of hospital quality of care.

This study shows that a facilities' risk of HA-MRSA infection admissions is driven, in part, by the proportion of patients they admit with high-risk attributes, such as diabetes and renal failure. Not surprisingly, these attributes are well known to be associated with a higher risk of HA-MRSA infection.[7-9,30]

In addition, our study found that the proportion of admitted patients from lower socioeconomic backgrounds was also in- dependently predictive of a hospitals' proportion of HA-MRSA infections. The availability of resources in the home environment could influence the risk of HA infections that manifest in the immediate postdischarge period. For MRSA specifically, studies have shown that recently hospitalized MRSA carriers have a higher risk of invasive MRSA disease that persists for many months following discharge.31-33 Currently, neither public reporting outlets nor hospital surveillance methods account for HA-MRSA infections in the postdischarge period.6 Postdischarge infection risk could be influenced by the inability to afford prescribed medications—such as antibiotics or clean bandages for wounds—or the lack of a hygienic home environment. It could also be influenced by the inability to take time off from work, which could impact healing and recovery. Finally, lower educational status can impact the ability to understand instruction for proper home care. Our results are consistent with studies that have linked lower socioeconomic factors to wound and surgical site infections on an individual level.14,34 However, these findings further suggest that facility- level socioeconomic status case mix is an important and in- dependent predictor of HA-MRSA infection rates and should be accounted for when making interfacility comparisons. Lack of adjustment could particularly disadvantage safety net hospitals, which have limited ability to influence or improve the postdischarge environment.

In the case of California, the need to account for patient case mix when publicly reporting hospital MRSA bloodstream infection rates is not unrecognized.[25] However, current methods are insufficient. After stratification by hospital type, un- adjusted MRSA bloodstream infection rates are reported alongside a value indicating a hospital's relative case mix index. The case mix index is meant to reflect the severity of illness for a hospital's population by accounting for factors such as age, length of hospitalization, and type of care received. Although an important attempt to identify hospitals treating patients with increased severity illness, case mix index is a standard index and may not focus on comorbidities known to be relevant to the outcome being reported. In addition, it is unlikely that readers are able to meaningfully understand the impact that the listed case mix index might have on reported

FIGURE 1. Raw (r) and adjusted (a) hospital-associated methicillin-resistant *Staphylococcus aureus* (HA-MRSA) infection rate for a random sample of 20 community hospitals (*A*) and teaching hospitals (*B*) in California, 2009-2010. Each hospitals' HA-MRSA infection rate is given as a confidence interval in pairs as both raw and adjusted predicted performance. Interval shifts after adjustment is associated with regression to the mean and hospital-level adjustment factors. Width of the interval after adjustment is proportional to the standard deviation of the Poisson distribution. The vertical dashed line represents the states' average performance.

rates. Rather, the interpretation by the public and stakeholders is driven by the ranking itself, regardless of the index or the rankings' statistical meaningfulness.

This work suggests an alternative method by which infection rates are directly adjusted for the consumer to allow for accurate comparisons. This method includes quantifying the effects of case load on infection proportions and separating them from the adjusted relative performance of an individual hospital. This study further shows that even a simple ranking based on hospital adjustment factors will change the relative position of hospitals as based on raw performance alone. Although the California 3-tiered performance metric represents a real-world application for reporting HA-MRSA infections, our exploration shows that any system that strictly follows that metric conflates 2 separable aspects of performance.

TABLE 3. Comparison of Performance Categorization Using Raw and Adjusted Values for Hospitals' Proportion of Hospital-Associated Methicillin-Resistant *Staphylococcus aureus* (HA-MRSA) Infections in California Hospitals

	Raw performance		
Adjusted performance	Poor	Average	Superior
Community hospital			
Poor	41	8	0
Average	12	159	35
Superior	0	5	36
Teaching hospital			
Poor	3	0	0
Average	1	10	1
Superior	0	0	5

NOTE. Adjusted performance accounts for hospital-level characteristics associated with a hospitals' proportion of HA-MRSA infection admission. Through the creation of an exact Poisson 95% confidence interval (CI) for each hospital's proportions, hospitals were placed into poor-, average-, and superior-performance categories if the state's mean proportion was above, within, or below a hospital's 95% CI, respectively.

Our study has several limitations and strengths. First, use of these readily available data sets cannot account for all factors associated with infection risk, such as invasive device use or proportion of intensive care unit admissions, which have been shown to be associated with MRSA carriage and infection.32,35,36 Second, use of these data sets is subject to further validation studies. Despite validated methodology for its use in identifying patient comorbidities,17 a previous version of MRSA ICD-9 codes has been shown to have limitations in ascertainment of MRSA disease.37,38 Although our study uses more recently revised MRSA ICD-9 codes (updated in 2008) meant to increase the specificity and sensitivity for capturing MRSA infection, other databases—such as the Center for Disease Control's National Healthcare Safety Net- work—could be used for identifying HA-MRSA infections. Nonetheless, many past studies have used administrative codes for national estimates of MRSA infection.1,39,40 Finally, this study may not be generalizable to the United States as a whole, and additional studies may be needed to identify facility-level predictors for long-term acute care facilities and skilled nursing facilities.

In conclusion, we used readily available and routinely up- dated standardized electronic databases to show that adjusting for facility-level case mix causes large and meaningful shifts in hospital benchmarking. This indicates that publicly re- porting raw rates may be misleading to patients and providers and likely provides a disadvantage to hospitals that care for the sickest and poorest patients. Public health officials could use these data sets to adjust for nonmodifiable facility-level factors and enable rate comparisons to be focused on hospital performance related to modifiable prevention strategies that can impact patient care.

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references

1. Klein E, Smith DL, Laxminarayan R. Hospitalizations and deaths caused by methicillin-resistant *Staphylococcus aureus*, United States, 1999–2005. *Emerg Infect Dis* 2007;13(12):1840–1846.
2. Jarvis WR, Jarvis AA, Chinn RY. National prevalence of methicillin-resistant *Staphylococcus aureus* in inpatients at United States health care facilities, 2010. *Am J Infect Control* 2012;40(3): 194–200.
3. Sievert DM, Ricks P, Edwards JR, et al. Antimicrobial-resistant pathogens associated with healthcare-associated infections: sum- mary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2009–2010. *Infect Control Hosp Epidemiol* 2013;34(1):1-14.
4. Huang SS, Hinrichsen VL, Datta R, et al. Methicillin-resistant *Staphylococcus aureus* infection and hospitalization in high-risk patients in the year following detection. *PLoS One* 2011;6(9): e24340.
5. Centers for Medicare and Medicaid Services (CMS). *Proposed Rule and Correction Notice: CMS-1588-P and CMS-1588-CN*. Baltimore, MD: CMS, 2012.
6. Avery TR, Kleinman KP, Klompas M, Aschengrau A, Huang SS. Inclusion of 30-day postdischarge detection triples the incidence of hospital-onset methicillin-resistant *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 2012;33(2):114–121.
7. Warren DK, Guth RM, Coopersmith CM, Merz LR, Zack JE, Fraser VJ. Epidemiology of methicillin-resistant *Staphylococcus aureus* colonization in a surgical intensive care unit. *Infect Control Hosp Epidemiol* 2006;27(10):1032-1040.
8. Marshall C, Wolfe R, Kossmann T, Wesselingh S, Harrington G, Spelman D. Risk factors for acquisition of methicillin-resistant *Staphylococcus aureus* (MRSA) by trauma patients in the intensive care unit. *J Hosp Infect* 2004;57(3):245–252.
9. Pujol M, Pena C, Pallares R, Ayats J, Ariza J, Gudiol F. Risk factors for nosocomial bacteremia due to methicillin-resistant *Staphylococcus aureus*. *Eur J Clin Microbiol Infect Dis* 1994;13(1): 96–102.
10. State of California Office of Statewide Health Planning and De- velopment (OSHPD). *Inpatient Hospital Discharges*. Sacramento, CA: OSHPD, 2009 and 2010.
11. Glance LG, Dick AW, Osler TM, Mukamel DB. Accuracy of

hospital report cards based on administrative data. *Health Serv Res* 2006;41(4):1413–1437.

12. Goldman LE, Chu PW, Prothro C, Osmond D, Bindman AB. *Accuracy of Condition Present on Admission, Do Not Resuscitate, and E-Codes in California Patient Discharge Data*. San Francisco, CA: University of California, 2011.
13. US Census Bureau. *American Community Survey*. Washington, DC: US Census Bureau, 2005–2010.
14. Bagger JP, Zindrou D, Taylor KM. Postoperative infection with meticillin-resistant *Staphylococcus aureus* and socioeconomic background. *Lancet* 2004;363(9410):706–708.
15. Huang SS, Finkelstein JA, Rifas-Shiman SL, Kleinman K, Platt R. Community-level predictors of pneumococcal carriage and resistance in young children. *Am J Epidemiol* 2004;159(7):645-654.
16. California Department of Public Health (CDPH). *Methicillin- Resistant* Staphylococcus aureus *(MRSA) and Vancomycin-Re- sistant Enterococci (VRE) Bloodstream Infections (BSI) in Cali- fornia Hospitals, 2011*. Sacramento, CA: CDPH, 2011. http://www.cdph.ca.gov/programs/hai/Pages/MRSAandVRE-Report.aspx.
17. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* 1998;36(1): 8-27.
18. Healthcare Cost and Utilization Project. Comorbidity Software, Version 3.7. Rockville, MD: Agency for Healthcare Research and Quality. http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp. Accessed May 14, 2014.
19. US Census Bureau. *ZIP Code Tabulation Areas (ZCTAs)*. Wash- ington, DC: US Census Bureau, 2014. http://www.census.gov/geo/reference/zctas.html. Accessed April 1, 2014.
20. Murphy CR, Avery TR, Dubberke ER, Huang SS. Frequent hos- pital readmissions for *Clostridium difficile* infection and the im- pact on estimates of hospital-associated *C. difficile* burden. *Infect Control Hosp Epidemiol* 2012;33(1):20–28.
21. Ash AS, Fienberg SE, Louis TA, Normand SL, Stukel TA, Utts J. *Statistical Issues in Assessing Hospital Performance*. Baltimore, MD: Centers for Medicare and Medicaid Services, 2011.
22. Lee Y, Nelder JA. Hierarchical generalised linear models: a syn- thesis of generalised linear models, random-effect models and structured dispersions. *Biometrika* 2001;88(4):987–1006.
23. Lehmann E. *Nonparametrics: Statistical Methods Based on Ranks*. San Francisco, CA: Holden-Day, 1975.
24. *Payment Adjustment for Conditions Acquired in Hospitals.* Patient Protection and Affordable Care Act, HR 3590. 2009, 111th Con- gress, 2009–2010.
25. California Department of Public Health (CDPH). *Incidence Rates of Hospital-Onset Methicillin-Resistant* Staphylococcus aureus *Bloodstream Infections Reported by California Acute Care Hospitals, Restricted to Hospitals that Reported Twelve Months of Data, January 2011–December 2011*. Sacramento, CA: CDPH, 2011. http://www.cdph.ca.gov/programs/hai/Pages/MRSAandVRE-Report.aspx. Accessed August 16, 2012.
26. Missouri Department of Health and Senior Services (DHSS). *Health Care-Associated Infection Reporting*. Jefferson City, MO: DHSS, 2014. http://health.mo.gov/data/hai/drive_noso.php.
27. Daneman N, Stukel TA, Ma X, Vermeulen M, Guttmann A. Reduction in *Clostridium difficile* infection rates after mandatory hospital public reporting: findings from a longitudinal cohort study in Canada. *PLoS Med* 2012;9(7):e1001268.
28. Blum JA, Freeman K, Dart RC, Cooper RJ. Requirements and definitions in conflict of interest policies of medical journals. *JAMA* 2009;302(20):2230–2234.
29. Fung CH, Lim YW, Mattke S, Damberg C, Shekelle PG. Sys- tematic review: the evidence that publishing patient care per- formance data improves quality of care. *Ann Intern Med* 2008; 148(2):111–123.
30. Coello R, Glynn JR, Gaspar C, Picazo JJ, Fereres J. Risk factors for developing clinical infection with methicillin-resistant *Staph- ylococcus aureus* (MRSA) amongst hospital patients initially only colonized with MRSA. *J Hosp Infect* 1997;37(1):39–46.
31. Lucet JC, Paoletti X, Demontpion C, et al. Carriage of methicillin-resistant *Staphylococcus aureus* in home care settings: prev- alence, duration, and transmission to household members. *Arch Intern Med* 2009;169(15):1372–1378.
32. Huang SS, Rifas-Shiman SL, Warren DK, et al. Improving methicillin-resistant *Staphylococcus aureus* surveillance and reporting in intensive care units. *J Infect Dis* 2007;195(3):330–338.
33. Robicsek A, Beaumont JL, Peterson LR. Duration of colonization with methicillin-resistant *Staphylococcus aureus*. *Clin Infect Dis* 2009;48(7):910–913.
34. Maree CL, Eells SJ, Tan J, et al. Risk factors for infection and colonization with community-associated methicillin-resistant *Staphylococcus aureus* in the Los Angeles County jail: a case-control study. *Clin Infect Dis* 2010;51(11):1248–1257.
35. Robicsek A, Beaumont JL, Paule SM, et al. Universal surveillance for methicillin-resistant *Staphylococcus aureus* in 3 affiliated hos- pitals. *Ann Intern Med* 2008;148(6):409-418.
36. Vincent JL, Rello J, Marshall J, et al. International study of the prevalence and outcomes of infection in intensive care units. *JAMA* 2009;302(21):2323–2329.
37. Schaefer MK, Ellingson K, Conover C, et al. Evaluation of In- ternational Classification of Diseases, Ninth Revision, Clinical Modification Codes for reporting methicillin-resistant *Staphy- lococcus aureus* infections at a hospital in Illinois. *Infect Control Hosp Epidemiol* 2010;31(5):463–468.
38. David MZ, Medvedev S, Hohmann SF, Ewigman B, Daum RS. Increasing burden of methicillin-resistant *Staphylococcus aureus* hospitalizations at US academic medical centers, 2003-2008. *Infect Control Hosp Epidemiol* 2012;33(8):782–789.
39. Gerber JS, Coffin SE, Smathers SA, Zaoutis TE. Trends in the incidence of methicillin-resistant *Staphylococcus aureus* infection in children's hospitals in the United States. *Clin Infect Dis* 2009; 49(1):65–71.
40. Kuehnert MJ, Hill HA, Kupronis BA, Tokars JI, Solomon SL, Jernigan DB. Methicillin-resistant *Staphylococcus aureus* hospi- talizations, United States. *Emerg Infect Dis* 2005; 11(6):868–872.