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# Medicare Claims Can Be Used to Identify US Hospitals With Higher Rates of Surgical Site Infection Following Vascular Surgery

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**Background:** Surgical site infections (SSIs) following vascular surgery have high morbidity and costs, and are increasingly tracked as hospital quality measures.

**Objective:** To assess the ability of Medicare claims to identify US hospitals with high SSI rates after vascular surgery.

**Research Design:** Using claims from fee-for-service Medicare enrollees of age 65 years and older who underwent vascular surgery from 2005 to 2008, we derived hospital rankings using previously validated codes suggestive of SSI, with individual-level adjustment for age, sex, and comorbidities. We then obtained medical records for validation of SSI from hospitals ranked in the best and worst deciles of performance, and used logistic regression to calculate the risk-adjusted odds of developing an SSI in worst-decile versus best-decile hospitals.

**Results:** Among 203,023 Medicare patients who underwent vascular surgery at 2512 US hospitals, a patient undergoing surgery in a hospital ranked in the worst-performing decile based on claims had 2.5 times higher odds of developing a chart-confirmed SSI relative to a patient with the same age, sex, and comorbidities in a hospital ranked in the best-performing decile (95% confidence interval, 2.0–3.1). SSI confirmation among patients with claims suggesting infection was similar across deciles, and we found similar findings in analyses limited to deep and organ/space SSIs. We report on diagnosis codes with high sensitivity for identifying deep and organ/ space SSI, with one-to-one mapping to ICD-10-CM codes.

**Conclusions:** Claims-based surveillance offers a standardized and objective methodology that can be used to improve SSI surveillance and to validate hospitals' publicly reported data.

**Key Words:** health care reform, hospital quality, Medicare, claims data, health care associated infection

Approximately 140,000 patients undergo vascular surgery annually in US hospitals.<sup>1</sup> Postoperative complications, including surgical site infections (SSIs), are self-reported to the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN).<sup>2</sup> These data suggest that 5.9% of vascular surgery patients develop an SSI.<sup>3</sup> Actual rates are likely 50% to 100% higher, as infections often occur postdischarge, in a variety of health care settings, with case identification dependent upon surveillance methods.<sup>4,7</sup>

SSIs are associated with substantial morbidity, mortality, and cost. The average

attributable cost per infection following vascular surgery ranges from \$10,000 to \$25,000, with an average increase in hospital length of stay of 4–10 days.<sup>8,9</sup> Infections involving the fascia and muscle or major blood vessels (deep and organ/space SSIs) triple surgery-associated mortality.<sup>10</sup> Infections involving vascular grafts result in amputation in up to 25% of patients due to blood loss to the affected limb.<sup>11</sup>

These infections may be prevented by the implementation of standardized “bundles” focused on best clinical practice, including improvements in perioperative antibiotic prophylaxis, surgical skin preparation, perioperative normothermia, and strict adherence to sterile technique in the operating room.<sup>10,12</sup> Thus, the national Surgical Care Improvement Project has focused on reducing surgical complications following high-volume, high-risk procedures, including vascular surgery.<sup>13–15</sup> To date, multiple Surgical Care Improvement Project procedures have been targeted by states for public reporting,<sup>16</sup> and California and Texas currently require reporting of vascular surgery SSI data as part of legislated prevention efforts.<sup>17,18</sup>

To provide better transparency and a more standardized comparison of outcomes across US hospitals, the Centers for Medicare & Medicaid Services (CMS) has partnered with the CDC to collect data on deep and organ/space SSIs reported to NHSN.<sup>19</sup> These data are available on the Hospital Compare Web site for colon surgery and abdominal hysterectomy.<sup>20</sup> Beginning in financial year 2016, these SSI rates will be included in the score calculation for the Hospital Inpatient Value-Based Purchasing (VBP) Program, and additionally used as measures in the Hospital Acquired Condition Reduction Program.<sup>21</sup> By incentivizing quality outcomes, the goal of these programs is to prompt hospitals to take steps toward lowering SSI rates.

The validity of interhospital comparisons, however, depends heavily on hospital-level case identification. Despite specific CDC criteria, case finding varies substantially depending on the resources that hospitals commit to SSI surveillance, including the method of identifying cases (eg, microbiology data, administrative data, surgeon report, reoperations, readmissions, antibiotic use) and the resources to review medical records. For this reason, the CMS Inpatient Quality Reporting Program is evaluating validation strategies to ensure uniform and complete case finding.

Data increasingly support the use of diagnosis and procedure codes found in submitted claims to comprehensively identify “candidate SSI events” for chart review.<sup>5,6,22–30</sup> This strategy is being used by hospitals and state SSI programs to improve reporting,<sup>26,29,30</sup> and by CMS during validation survey.<sup>22</sup>

In a pilot study, record review triggered by claims codes suggestive of SSI following vascular surgery detected more SSIs than traditional surveillance. Although traditional surveillance detected SSIs following 4.4% of vascular procedures, claims-based surveillance detected SSIs following 7.9% of vascular procedures, with 1 SSI confirmed for every 2 cases reviewed.<sup>6</sup> This compares to an average of 16 cases reviewed by infection control personnel for every SSI confirmed using traditional surveillance methods.<sup>6</sup>

The aim of the current study was to validate the use of diagnosis and procedure codes in claims data as a surrogate marker of SSI following vascular surgery among fee-for-service Medicare enrollees aged 65 years and older in US acute care hospitals.

## METHODS

### Study Design and Patient Population

This retrospective cohort study used data on a sample of fee-for-service Medicare enrollees aged 65 years and older who underwent vascular surgery in US acute care hospitals from January 1, 2005, through December 31, 2008. We screened all Medicare A and B administrative claims submitted within 60 days after surgery for diagnosis and procedure codes suggestive of SSI. The vascular surgery and SSI

codes (Appendix 1) are similar to a previous pilot study.<sup>6,13</sup> To avoid uncertainty in attributing an SSI to a specific procedure, we excluded patients who underwent another major surgery within 60 days before vascular surgery.<sup>13</sup> We also excluded patients with multiple surgical dates for vascular surgery during their index hospitalization. Finally, we excluded patients with claims suggestive of infection at the surgical site in the 30 days before surgery (Appendix 1). For eligible patients who underwent another major surgery in the 60-day postoperative surveillance window, we evaluated claims only for the period between the vascular surgery and the subsequent surgery.<sup>13</sup> The study was approved by the Harvard Pilgrim Health Care institutional review board.

### Ranking of US Hospitals

On the basis of Medicare claims suggestive of SSI, we produced a risk-adjusted ranking of all US acute care hospitals performing vascular surgery on Medicare patients during the study period.<sup>25,27</sup> The rankings were derived from a generalized linear mixed model,<sup>31</sup> with risk adjustment for patients' age, sex, and coded Romano comorbidities for a Medicare population shown to be predictive of SSI in prior work.<sup>25,27,32,33</sup> The rankings used empirical Bayes estimators (predicted random effects), which drew hospitals with low procedure volume toward the mean, due to their greater variability.<sup>34-36</sup> On the basis of the risk-adjusted rankings, hospitals were grouped into deciles.

### Clinical Chart Review

Using a simple random selection method, we selected 1000 patients with at least 1 SSI code, 500 each from hospitals in the best-performing and the worst-performing deciles. For each selected patient, we requested all inpatient and outpatient records flagged for review based on submitted diagnosis and procedure codes suggestive of SSI.

Records were reviewed for the presence of an SSI using CDC/NHSN criteria.<sup>37</sup> Chart abstractions were completed by trained research assistants and verified by an infectious diseases physician with expertise in hospital epidemiology who was blinded to the decile from which each patient was selected. For each chart-confirmed SSI, we collected data on depth of infection (superficial, deep, or organ/space) and time since vascular surgery. When an SSI was not confirmed, alternative reasons for the infection codes were recorded.

### Primary Analysis of All SSIs

Patients with a confirmed SSI were those with chart confirmation of SSI. Patients with no confirmed SSI were: (1) patients with Z1 SSI code selected for review who did not meet CDC/NHSN criteria for SSI (including those whose medical records were either not received or contained insufficient data); and (2) a proportional sample of patients treated at hospitals from the same decile drawn randomly from among patients with no SSI code (Fig. 1). This selection of an equal proportion of flagged and non-flagged patients is equivalent to a stratified sample within each decile. We assumed that patients without an SSI code did not have an SSI, because earlier work found that claims-based surveillance had a very high sensitivity.<sup>6</sup>

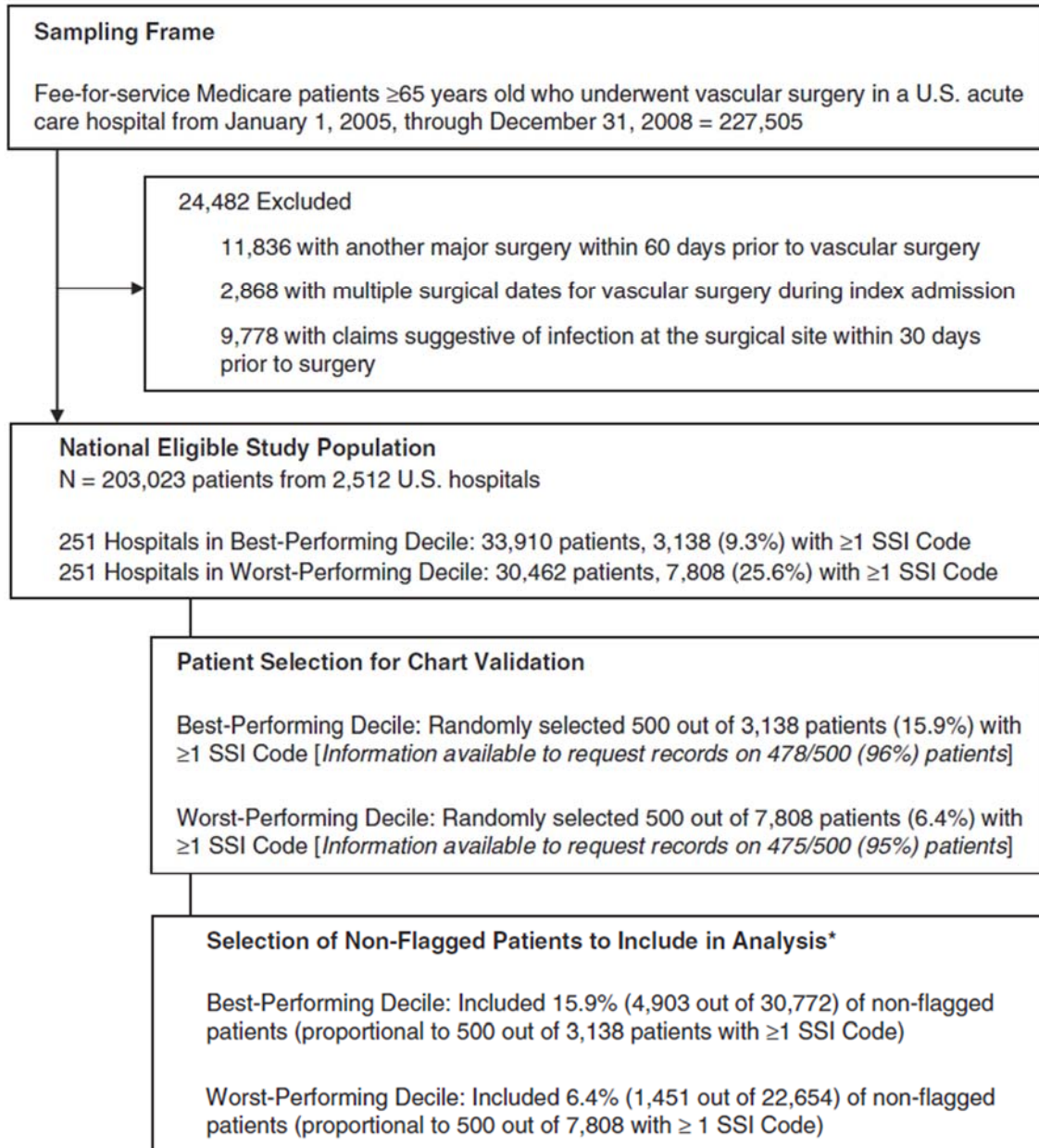


FIGURE 1. Study population. \*Selection of flagged and non-flagged patients is equivalent to a stratified sample within each decile, sampling an equal proportion of flagged and non-flagged cases. SSI indicates surgical site infection.

We used a  $w^2$  test to compare the proportion of claims-identified patients with SSI confirmation in worst-decile versus best-decile hospitals. We also performed logistic regression evaluating whether surgery performed in worst-decile versus best-decile hospitals affected the odds of infection. We controlled for and assessed the effects of age, sex, and coded Romano comorbidities for a Medicare population.<sup>32,33</sup> All analyses were performed in SAS 9.3 (SAS Institute, Cary, NC).

## Secondary Analysis of Deep and Organ/Space SSIs

We further assessed whether undergoing vascular surgery in a worst-decile versus best-decile hospital was associated with a higher rate of deep and organ/space SSI based on chart review. Using sensitivity and positive predictive value, we selected codes that best identified deep and organ/space SSIs. The branch-and-bound algorithm of Furnival and Wilson<sup>38</sup> was used to select the best code combinations. We considered the 100 best models for each number of predictors, ranging from a single code to all infection codes. In cases with multiple possible code combinations for the highest sensitivity, we applied clinical judgment to select the codes most consistent with SSI. Our goal was to achieve a sensitivity >90% for the final code sets.

## RESULTS

### Study Population

There were 203,023 eligible Medicare patients who underwent vascular surgery in 2512 US hospitals from January 1, 2005, through December 31, 2008 (Fig. 1). We compared the comorbidities in patients with a code suggestive of SSI versus those in patients with no SSI code (Table, Supplemental Digital Content 1, <http://links.lww.com/MLR/A797>). The rates of diabetes with end-organ damage, congestive heart failure, and moderate to severe renal disease were 10 percentage points higher in patients with a code suggestive of SSI. Other comorbidities had similar rates between the 2 groups.

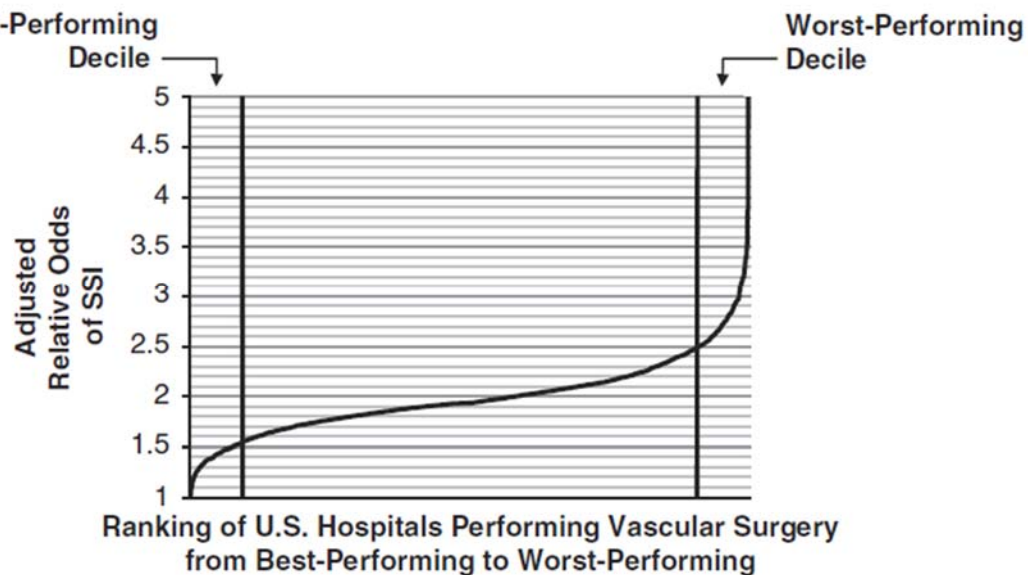


FIGURE 2. Adjusted relative odds of surgical site infection for US hospitals performing vascular surgery on Medicare patients. Each hospital is represented by a point on the plotted line (total of 2512 US acute care hospitals). Best-decile and worst-decile hospitals are delineated with vertical lines (251 hospitals per decile).

### Hospital Performance Based on Claims Suggestive of SSI

Across the 2512 US hospitals that performed vascular surgery, the median percentage of vascular surgery patients who were assigned a code suggestive of SSI

was 16% (interquartile range, 10%–22%). Figure 2 plots the adjusted odds of having at least 1 SSI code among Medicare patients who underwent vascular surgery at these hospitals from 2005 through 2008, relative to the best-performing hospital. As shown in Figure 1, 9.3% of patients in best-decile hospitals and 25.6% of patients in worst-decile hospitals had at least 1 code suggestive of SSI.

#### Chart Validation of All SSI

Of the 1000 patients randomly selected for clinical chart review, we had mailing information to request records for 953; 478 patients from best-decile hospitals and 475 patients from worst-decile hospitals. We requested 1611 charts: 749 linked to Part A inpatient claims, 149 linked to Part A outpatient claims, and 713 linked to Part B physician claims. This included requests for records following vascular surgery at approximately 75% of the hospitals in both the deciles.

We received sufficient records to determine whether an SSI was present for 90% of the requested Part A inpatient claims, 70% of the requested Part A outpatient claims, and 65% of the requested Part B physician claims. Overall, we received sufficient data to determine whether an SSI was present for 726 (76%) of the 953 patients for whom we had requested records. Of these patients, 101 (14%) underwent a central vascular procedure, 590 (81%) underwent a peripheral vascular procedure, and 35 (5%) underwent a combined central and peripheral vascular procedure. Table 1 shows the results for these 726 patients. Using CDC/NHSN criteria, we confirmed an SSI in 336 (46%) of the 726 reviewed patients with an SSI code, including confirmation of a deep or organ/space SSI in 149 (21%) of the 726 reviewed patients. Confirmed SSIs met the CDC/NHSN criteria as follows: (1) 15% of the superficial SSIs, 58% of the deep SSIs, and 74% of the organ/space SSIs were culture positive (organism isolated from an aseptically obtained culture); (2) the surgical incision was reopened by a surgeon and found to be culture positive (or not cultured) in 25% of the superficial SSIs, 66% of the deep SSIs, and 84% of the organ/space SSIs; and (3) SSIs were clearly documented by at least 1 surgeon or attending physician in the medical records for 93% of the superficial SSIs, 97% of the deep SSIs, and 98% of the organ/space SSIs.

Of the 390 patients who were not confirmed to have an SSI by CDC/NHSN criteria, 40 (10%) were found to have cellulitis at the site of the surgical incision not meeting criteria for superficial SSI, 40 (10%) were found to have a superficial SSI diagnosed >30 days after the surgical procedure, and 5 (1%) were found to have a deep or organ/space SSI > 30 days after the surgical procedure without the use of prosthetic graft requiring a longer surveillance window for case identification.

Eighty-two percent (277/336) of the confirmed SSIs were diagnosed after initial discharge from the hospital, including 152 (81%) of the 187 superficial SSIs and 125 (84%) of the 149 deep and organ/space SSIs. The median time to SSI following surgery was 15 days for superficial SSIs (interquartile range, 10–22 d), 19 days for deep and organ/space SSIs without prosthetic material (interquartile range, 14–25 d), and 23 days for deep and organ/space SSIs with prosthetic material (interquartile range, 16–35 d). Only 69% of the patients with an SSI diagnosed postdischarge were readmitted to the hospital where the surgery was performed (64% for superficial SSIs, 74% for deep and organ/space SSIs).

**TABLE 1.** Identification of Surgical Site Infection Among Patients With an SSI Code

	n (%)		P
	Best-Decile Hospitals (n = 383 Patients)	Worst-Decile Hospitals (n = 343 Patients)	
<b>No surgical site infection</b>	<b>204 (53)</b>	<b>186 (54)</b>	<b>0.85</b>
Noninfectious diagnosis	61 (16)	54 (16)	0.95
Infection at another site	102 (27)	88 (26)	0.83
Infection at site of surgical incision not meeting CDC/NHSN SSI criteria*	41 (11)	44 (13)	0.44
<b>Surgical site infection</b>	<b>179 (47)</b>	<b>157 (46)</b>	<b>0.85</b>
Superficial	103 (27)	84 (24)	0.51
Deep or organ/space	76 (20)	73 (21)	0.70

\*Cellulitis at site of surgical incision not meeting criteria for superficial SSI (13 in best-decile hospitals, 27 in worst-decile hospitals), superficial SSI > 30 days following surgical procedure (27 in best-decile hospitals, 13 in worst-decile hospitals), and deep or organ/space SSI > 30 days following a surgical procedure without the use of prosthetic graft (1 in best-decile hospitals, 4 in worst-decile hospitals).

CDC indicates Centers for Disease Control and Prevention; NHSN, National Healthcare Safety Network; SSI, surgical site infection.

### Chart Confirmation of SSI in Worst-Decile Versus Best-Decile Hospitals

Among patients with submitted claims suggestive of SSI in best-decile and worst-decile hospitals, clinical chart review confirmed an SSI in an equal proportion ( $P$ -value assessing null hypothesis of equal rates = 0.85). The distribution of superficial, deep, and organ/space SSIs was also similar among the patients flagged for review in these deciles (Table 1).

Because a higher proportion of patients had submitted claims suggestive of SSI in worst-decile versus best-decile hospitals, with similar confirmation rates between the 2 deciles, there was a significant difference in SSI rates between best-decile and worst-decile hospitals (3.3% vs. 8.2%;  $P < 0.01$  unadjusted). This difference was significant for superficial SSIs as well as for deep and organ/space SSIs (Table 2).

After adjustment for age, sex, and comorbidities, patients who underwent vascular surgery in worst-decile hospitals had a 2.5 times higher odds of developing an SSI compared with those who underwent vascular surgery in best-decile hospitals (95% confidence interval, 2.0–3.1). Diabetes with and without end-organ damage were significant predictors of SSI [OR = 1.8 (95% confidence interval, 1.4–2.3) and OR = 1.5 (95% confidence interval, 1.1–2.0), respectively]. Male sex and dementia were significantly protective [OR = 0.7 (95% confidence interval, 0.6–0.9) and OR = 0.5 (95% confidence interval, 0.3–1.0), respectively].

### Identification of Deep and Organ/Space SSIs Following Vascular Surgery

The results were similar when limited to deep and organ/space SSI. After adjustment for age, sex, and comorbidities, patients who underwent vascular surgery in worst-decile hospitals had a 2.7 times higher odds of developing a deep or organ/space SSI compared with those who underwent vascular surgery in best-decile hospitals (95% confidence interval, 1.9–3.7). Among patients with deep or organ/space SSIs, diabetes with end-organ damage remained a significant predictor of SSI [OR = 1.9 (95% confidence interval, 1.3–2.8)] and both male sex and dementia remained significantly protective [OR = 0.6 (95% confidence interval, 0.5–0.9) and OR = 0.2 (95% confidence interval, 0.1–0.9), respectively].

A total of 20 of the original 23 selected ICD-9 and CPT codes were used at least once in patients with a chart-confirmed deep or organ/space SSI (specific codes indicated in Appendix 1). In selecting codes that identified deep and organ/space SSI, we included all 154 patients found to have one of these infections, including the 5 patients diagnosed with a deep or organ/space SSI > 30 days after a vascular surgery without prosthetic graft. The ICD-9 procedure codes identified 91 (59%), the ICD-9 diagnosis codes identified 144 (94%), and the CPT codes identified 59 (38%). Together, the ICD-9 diagnosis and procedures codes identified 100% of the deep and organ/space SSIs. Thus, we opted to drop the CPT codes from further analyses.



Table 3 shows 3 different code combinations that achieved a sensitivity >90% for identification of deep and organ/space SSI following vascular surgery. A combination of 6 ICD-9 diagnosis and 5 ICD-9 procedure codes identified 100% of the validated deep and organ/space SSIs in our national sample. However, the selected ICD-9 procedure codes map to 442 different ICD-10 procedure codes (ICD-10-PCS). Therefore, we separately analyzed the performance of the ICD-9 diagnosis codes alone. As shown in Table 3, each of the selected ICD-9 diagnosis codes has a one-to-one mapping to an ICD-10 diagnosis code (ICD-10-CM). We present 2 combinations of ICD-9 diagnosis codes for consideration (ICD-9 diagnosis codes 996.60, 996.62, 998.51, and 998.59 ± 686.8 and 686.9). In the representative sample of patients on whom we performed record review for SSI validation, these ICD-9 diagnosis codes identified 92%–94% of the chart-confirmed deep and organ/space SSIs, with a positive predictive value of 20%–22%. The performance of these codes was the same in best-decile and worst-decile hospitals.

**TABLE 2.** Rate of Chart-confirmed Surgical Site Infections in Best-Decile Versus Worst-Decile Hospitals

	n (%)		<i>P</i>
	Best-Decile Hospitals (n = 5381 Patients <sup>a</sup> )	Worst-Decile Hospitals (n = 1926 Patients <sup>b</sup> )	
Surgical site infection	179 (3.3)	157 (8.2)	<0.01
Superficial	103 (1.9)	84 (4.4)	<0.01
Deep or organ/space	76 (1.4)	73 (3.8)	<0.01

<sup>a</sup>A total of 478 patients with records requested for chart validation of SSI code and 4903 patients selected as a proportional sample from patients without an SSI code (Fig. 1).

<sup>b</sup>A total of 475 patients with records requested for chart validation of SSI code and 1451 patients selected as a proportional sample from patients without an SSI code (Fig. 1).

## DISCUSSION

This national study found that US hospitals with higher rates of Medicare claims containing diagnosis and procedure codes suggestive of SSI following vascular surgery also had significantly higher rates of true infection. Claims-based surveillance is a sensitive, efficient, and standardized approach for identifying hospitals which are likely to have outlying rates of SSI among vascular surgery patients. This is important given that SSI rates are quality metrics increasingly tracked at both the state and national level, and linked to health care payment through value-based purchasing.

**TABLE 3.** Code Performance for Identification of Deep and Organ/Space Surgical Site Infections Following Vascular Surgery

ICD-9	ICD-10 Conversion	Description	Sensitivity	PPV
Code combination 1			100% (98%–100%)	17% (15%–20%)
54.0*	28 ICD-10-PCS codes	Incision of abdominal wall (drainage of abscess)*	Using these codes, we expect to find 100% of deep and organ/space SSIs, 1 for every 5.9 records reviewed	
86.01	48 ICD-10-PCS codes	Aspiration of skin and subcutaneous tissue (abscess, hematoma, seroma)		
86.04	281 ICD-10-PCS codes	Other incision with drainage of skin and subcutaneous tissue		
86.22	40 ICD-10-PCS codes	Excisional debridement of wound, infection, or burn		
86.28	45 ICD-10-PCS codes	Nonexcisional debridement of wound, infection, or burn		
686.8	L08.89	Other specified local infection of skin and subcutaneous tissue		
686.9	L08.9	Unspecified local infection of skin and subcutaneous tissue		
996.60	T85.79XA	Infection and inflammatory reaction due to unspecified device, implant, graft		
996.62	T82.7XXA	Infection and inflammatory reaction due to vascular device, implant, graft		
998.51	T81.4XXA	Infected postoperative seroma		
998.59	T81.4XXA	Other postoperative infection		
Code combination 2			94% (88%–97%)	20% (17%–23%)
686.8	L08.89	Other specified local infection of skin and subcutaneous tissue	Using these codes, we expect to find 94% of deep and organ/space SSIs, 1 for every 5 records reviewed	
686.9	L08.9	Unspecified local infection of skin and subcutaneous tissue		
996.60	T85.79XA	Infection and inflammatory reaction due to unspecified device, implant, graft		
996.62	T82.7XXA	Infection and inflammatory reaction due to vascular device, implant, graft		
998.51	T81.4XXA	Infected postoperative seroma		
998.59	T81.4XXA	Other postoperative infection		
Code combination 3			92% (86%–95%)	22% (19%–25%)
996.60	T85.79XA	Infection and inflammatory reaction due to unspecified device, implant, graft	Using these codes, we expect to find 92% of deep and organ/space SSIs, 1 for every 4.5 records reviewed	
996.62	T82.7XXA	Infection and inflammatory reaction due to vascular device, implant, graft		
998.51	T81.4XXA	Infected postoperative seroma		
998.59	T81.4XXA	Other postoperative infection		

Data presented with 95% confidence intervals.

\*This code only applies to central vascular procedures.

PPV indicates positive predictive value; SSI, surgical site infection.

Twenty-one US states have legislation requiring SSI monitoring and reporting, with an increasing number of states making these data publicly available for consumer review.<sup>18</sup> From 2008 through 2011, the CDC reported a 17% reduction in national SSI rates,<sup>39</sup> with 27 states participating in SSI Prevention Collaboratives.<sup>40</sup> Nevertheless, substantial heterogeneity exists in SSI monitoring and reporting across procedures and across facilities, and there is a need for efficient and comprehensive methods aimed at standardizing SSI surveillance and validation.

We previously demonstrated that national Medicare claims can identify US hospitals with significantly higher rates of SSI following coronary artery bypass graft surgery and hip arthroplasty.<sup>25,27</sup> The findings presented in the current paper further support the use of claims for SSI surveillance following vascular procedures, which are associated with the second highest infection rate in US hospitals, following colon procedures.<sup>3</sup>

Overall, the rate of confirmed SSIs among claims-identified charts was similar in the best and worst deciles, suggesting roughly uniform coding practices across hospitals. Thus, although not all patients with a code suggestive of SSI will have a confirmed infection, the relative rate of patients with one or more of these codes at each hospital is an effective means of comparing performance across hospitals. Still, if these codes are used to track performance, it will be important to monitor for intentional use of alternative codes. It will be similarly important to consider surveillance of these patients beyond the hospital where the surgery was performed.

A strength of claims-based surveillance is that it standardizes detection of postdischarge SSIs. Prior work has suggested that variability in postdischarge SSI surveillance methods dramatically affects rankings, with hospitals performing more robust postdischarge surveillance appearing to have significantly higher SSI rates due to more frequent identification of superficial SSIs.<sup>41</sup> Our findings suggest that this is less of a concern with claims-based surveillance. Hospitals with higher rates of claims suggestive of SSI were found to have higher rates of both deep and organ/space SSIs and superficial SSIs.

Further, when focusing on surveillance for deep and organ/space SSIs, we found that the use of 4 ICD-9 diagnosis codes (996.60, 996.62, 998.51, and 998.59) could

identify >90% of patients with a chart-confirmed deep or organ/space SSI, without being overly burdensome on infection control staff responsible for hospital surveillance and reporting. The strong performance of these 4 codes in identifying SSIs has been suggested in prior studies.<sup>5</sup> In addition, these codes have a one-to-one mapping to ICD-10-CM codes, which are scheduled to replace the ICD-9 codes in October 2015.<sup>42</sup>

Our study has several limitations, particularly when considering the use of claims data to generate national rankings. First, although claims do allow for case-mix adjustment, it is possible that additional differences in case-mix or in coding practices might explain the outlier status of individual hospitals. Therefore, additional evaluation of hospitals is warranted once claims data signal a potentially high rate of SSIs. This might include case review by CMS or state health departments, with the opportunity to focus on quality improvement initiatives if a higher than expected SSI rate is confirmed. Second, it is important to point out the difficulty in assessing the performance of hospitals with low procedure volumes. The rates from these hospitals have large confidence intervals due to small denominators. Most low-volume hospitals were excluded from the best-performing or worst-performing deciles in our analysis because our ranking is based on empirical Bayes estimators. We feel this is appropriate, due to the uncertainty in estimating true infection rates from small numbers of procedures. Additional work is necessary to ensure that the performance of low-volume hospitals can be accurately assessed in national SSI benchmarking. Finally, patients whose claims did not contain one of our selected SSI codes were assumed to not have an SSI. This was based on the high sensitivity of the selected SSI codes in prior work.<sup>5,6</sup> The high sensitivity of claims for detecting SSI is also supported by a recent meta-analysis.<sup>43</sup> Still, it is possible that some patients who develop an SSI might not be identified by this approach.

In conclusion, claims data can be used to identify US hospitals with a higher SSI risk following vascular surgery. Given the biases inherent in self-reported rates by individual hospitals, claims-based surveillance offers a standardized and objective methodology that can be used by CMS and state health departments for validation of publicly reported data. Importantly, this method overcomes large differences in postdischarge capture of SSI rates and can reliably identify hospitals that might benefit from evaluation and quality improvement interventions aimed at reducing SSI events. The use of claims-based surveillance improves SSI detection and minimizes effort by hospital infection control staff by signaling high-risk charts for review and attention.

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## APPENDIX

**TABLE A1.** Vascular Surgical Site Infection Indicator Codes

Code Type	Code	Code Text
ICD-9 Procedure	54.0* <sup>†‡</sup>	Incision of abdominal wall (drainage of abscess)
ICD-9 Procedure	54.19* <sup>†</sup>	Other laparotomy (drainage of intraperitoneal abscess or hematoma)
ICD-9 Procedure	86.01 <sup>†‡</sup>	Aspiration of skin and subcutaneous tissue (abscess, hematoma, seroma)
ICD-9 Procedure	86.04 <sup>‡</sup>	Other incision with drainage of skin and subcutaneous tissue
ICD-9 Procedure	86.22 <sup>†‡</sup>	Excisional debridement of wound, infection, or burn
ICD-9 Procedure	86.28 <sup>†‡</sup>	Nonexcisional debridement of wound, infection, or burn
ICD-9 Diagnosis	686.8 <sup>‡</sup>	Other specified local infections of skin and soft tissue
ICD-9 Diagnosis	686.9 <sup>‡</sup>	Unspecified local infection of skin/soft tissue
ICD-9 Diagnosis	996.60 <sup>†‡</sup>	Infection and inflammatory reaction due to unspecified device, implant, graft
ICD-9 Diagnosis	996.62 <sup>†‡</sup>	Infection and inflammatory reaction due to vascular device, implant, graft
ICD-9 Diagnosis	998.51 <sup>‡</sup>	Infected postoperative seroma
ICD-9 Diagnosis	998.59 <sup>‡</sup>	Other postoperative infection
ICD-9 Diagnosis	998.6 <sup>‡</sup>	Persistent postoperative fistula
CPT	10140 <sup>‡</sup>	Incision and drainage of hematoma, seroma, or fluid collection
CPT	10160 <sup>†‡</sup>	Puncture aspiration of abscess, hematoma, bulla, or cyst
CPT	10180 <sup>†‡</sup>	Incision and drainage, complex, postoperative wound infection
CPT	12021	Treatment of superficial wound dehiscence; with packing
CPT	13160 <sup>‡</sup>	Secondary closure of surgical wound or dehiscence, extensive or complicated
CPT	20000 <sup>†</sup>	Incision of soft-tissue abscess, superficial
CPT	20005 <sup>†‡</sup>	Incision of soft-tissue abscess, deep
CPT	35840* <sup>†‡</sup>	Exploration for postoperative hemorrhage, thrombosis or infection, abdomen
CPT	35903 <sup>†‡</sup>	Excision of infected graft; extremity
CPT	35907* <sup>†‡</sup>	Excision of infected graft; abdomen

These codes were used to indicate a possible SSI following vascular surgery (ICD-9 procedure code 38.14, 38.16, 38.18, 38.34, 38.36, 38.37, 38.44, 38.48, 38.49, 38.64, 39.25, 39.26, or 39.29).

\*These codes were only used for central vascular procedures (ICD-9 procedure code 38.14, 38.16, 38.34, 38.36, 38.37, 38.44, 38.64, 39.25, 39.26, or any combination of vascular procedures that include one of these codes).

<sup>†</sup>We excluded patients who had any of these codes in the 30 days before surgery.

<sup>‡</sup>These codes were used in one or more cases with a chart-confirmed deep or organ/space surgical site infection.

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