2011

# Use of Medicare claims to rank hospitals by surgical site infection risk following coronary artery bypass graft surgery

Susan S. Huang
*Harvard University*

Hilary Placzek
*Harvard University*

James Livingston
*Harvard University*

Allen Ma
*Oklahoma Foundation for Medical Quality*

Fallon Onufrak
*Harvard University*

*See next page for additional authors*



## Recommended Citation

Huang, Susan S.; Placzek, Hilary; Livingston, James; Ma, Allen; Onufrak, Fallon; Lankiewicz, Julie; Kleinman, Ken; Bratzler, Dale; Olsen, Margaret A.; Lyles, Rosie; Khan, Yosef; Wright, Paula; Yokoe, Deborah S.; Fraser, Victoria J.; Weinstein, Robert A.; Stevenson, Kurt; Hooper, David; Vostok, Johanna; Datta, Rupak; Nsa, Wato; and Platt, Richard, "Use of Medicare claims to rank hospitals by surgical site infection risk following coronary artery bypass graft surgery." Infection Control and Hospital Epidemiology. 32, 8. 775-783. (2011).
https://digitalcommons.wustl.edu/open_access_pubs/787

Use of Medicare Claims to Rank Hospitals by Surgical Site Infection Risk following Coronary Artery Bypass Graft Surgery •

Author(s): Susan S. Huang, Hilary Placzek, James Livingston, Allen Ma, Fallon Onufrak, Julie Lankiewicz, Ken Kleinman, Dale Bratzler, Margaret A. Olsen, Rosie Lyles, Yosef Khan, Paula Wright, Deborah S. Yokoe, Victoria J. Fraser, Robert A. Weinstein, Kurt Stevenson, David Hooper, Johanna Vostok, Rupak Datta, Wato Nsa, Richard Platt

Reviewed work(s):
Source: *Infection Control and Hospital Epidemiology*, Vol. 32, No. 8 (August 2011), pp. 775-783
Published by: The University of Chicago Press on behalf of The Society for Healthcare Epidemiology of America
Stable URL: http://www.jstor.org/stable/10.1086/660874
Accessed: 03/03/2012 17:55

ORIGINAL ARTICLE

# Use of Medicare Claims to Rank Hospitals by Surgical Site Infection Risk following Coronary Artery Bypass Graft Surgery

Susan S. Huang, MD, MPH;[1,2] Hilary Placzek, MPH;[1] James Livingston, MBA;[1] Allen Ma, PhD;[3] Fallon Onufrak, BS;[1] Julie Lankiewicz, MPH;[1] Ken Kleinman, ScD;[1] Dale Bratzler, DO;[3] Margaret A. Olsen, PhD, MPH;[4] Rosie Lyles, MD, MHA;[5] Yosef Khan, MD, MPH;[6] Paula Wright, RN, BSN;[7] Deborah S. Yokoe, MD, MPH;[8] Victoria J. Fraser, MD;[4] Robert A. Weinstein, MD;[5] Kurt Stevenson, MD, MPH;[6] David Hooper, MD;[7] Johanna Vostok, MPH;[1] Rupak Datta, MPH;[1,2] Wato Nsa, MD, PhD;[3] Richard Platt, MD, MS[1,8]

OBJECTIVE. To evaluate whether longitudinal insurer claims data allow reliable identification of elevated hospital surgical site infection (SSI) rates.

DESIGN. We conducted a retrospective cohort study of Medicare beneficiaries who underwent coronary artery bypass grafting (CABG) in US hospitals performing at least 80 procedures in 2005. Hospitals were assigned to deciles by using case mix–adjusted probabilities of having an SSI-related inpatient or outpatient claim code within 60 days of surgery. We then reviewed medical records of randomly selected patients to assess whether chart-confirmed SSI risk was higher in hospitals in the worst deciles compared with the best deciles.

PARTICIPANTS. Fee-for-service Medicare beneficiaries who underwent CABG in these hospitals in 2005.

RESULTS. We evaluated 114,673 patients who underwent CABG in 671 hospitals. In the best decile, 7.8% (958/12,307) of patients had an SSI-related code, compared with 24.8% (2,747/11,068) in the worst decile ($P < .001$). Medical record review confirmed SSI in 40% (388/980) of those with SSI-related codes. In the best decile, the chart-confirmed annual SSI rate was 3.2%, compared with 9.4% in the worst decile, with an adjusted odds ratio of SSI of 2.7 (confidence interval, 2.2–3.3; $P < .001$) for CABG performed in a worst-decile hospital compared with a best-decile hospital.

CONCLUSIONS. Claims data can identify groups of hospitals with unusually high or low post-CABG SSI rates. Assessment of claims is more reproducible and efficient than current surveillance methods. This example of secondary use of routinely recorded electronic health information to assess quality of care can identify hospitals that may benefit from prevention programs.

*Infect Control Hosp Epidemiol* 2011;32(8):775-783

Surgical site infections (SSIs) are a leading adverse outcome of medical care, with nearly 500,000 US cases annually.[1-5] SSI prevention is a major goal of the Joint Commission,[6] the Centers for Disease Control and Prevention (CDC),[7] the Centers for Medicare and Medicaid Services (CMS) Surgical Care Improvement Program,[8] and the Institute for Healthcare Improvement.[9] These initiatives depend on accurate assessment of hospital infection rates. However, current SSI surveillance performed by hospital-based infection preventionists uses a labor-intensive process that is difficult to standardize. Most SSIs have an incubation period that is longer than postoperative stays, which further confounds surveillance by hospital-based detection programs.[10-16] In addition, current reporting standards fail to adjust for hospital case mix and ignore well-established SSI risk factors, such as age and diabetes.[17-20] This can unfairly disadvantage hospitals serving sicker patients. Currently reported SSI rates are thus a poor foundation for evaluating hospital performance.

Claims data have several potential advantages for simplifying and standardizing SSI detection: (1) uniform identification of subsequent procedures suggesting SSI (eg, reoperation, abscess debridement); (2) detection of care in all settings, including outpatient facilities and other hospitals; (3) existence of validated case mix adjustment methods;[18-22] and (4) ready availability and ease of analysis.

We previously showed that claims data can successfully

Affiliations: 1. Department of Population Medicine, Harvard Medical School and Harvard Pilgrim Health Care Institute, Boston, Massachusetts; 2. Division of Infectious Diseases and Health Policy Research Institute, University of California Irvine School of Medicine, Irvine, California; 3. Oklahoma Foundation for Medical Quality, Oklahoma City, Oklahoma; 4. Division of Infectious Diseases, Washington University School of Medicine, St. Louis, Missouri; 5. Department of Medicine, Cook County Hospital, Chicago, Illinois; 6. Department of Infection Control, Ohio State University School of Medicine, Columbus, Ohio; 7. Department of Infection Control, Massachusetts General Hospital, Boston, Massachusetts; 8. Channing Laboratory, Department of Medicine and Department of Infection Control, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts.

Received January 31, 2011; accepted March 28, 2011; electronically published June 15, 2011.

 0899-823X/2011/3208-0007$15.00. DOI: 10.1086/660874

TABLE 1. ICD-9 Diagnostic and CPT Procedure Codes Used as Surgical Site Infection Indicators following Coronary Artery Bypass Surgery

| Code | Code text |
|---|---|
| ICD-9 | |
| 34.00 | Incision of chest wall and pleura |
| 34.01 | Incision of chest wall |
| 34.02 | Exploratory thoracotomy |
| 34.10 | Incision of mediastinum |
| 86.01 | Aspiration of skin and subcutaneous tissue (abscess, hematoma, seroma) |
| 86.04 | Other incision with drainage of skin and subcutaneous tissue |
| 86.09 | Other incision of skin and subcutaneous tissue |
| 86.22 | Excisional debridement of wound, infection, or burn |
| 86.28 | Nonexcisional debridement of wound, infection, or burn |
| 91.71 | Operative wound: gram stain |
| 91.72 | Operative wound: culture |
| 91.73 | Operative wound: culture and sensitivity |
| 513.1 | Abscess of mediastinum |
| 519.2 | Mediastinitis |
| 682.2 | Cellulitis of trunk |
| 682.3 | Cellulitis of upper arm/forearm |
| 682.8 | Cellulitis, other specified sites |
| 686.8 | Other specified local infections of skin and soft tissue |
| 686.9 | Unspecified local infection of skin/soft tissue |
| 730.00 | Acute osteomyelitis, site unspecified |
| 730.08 | Acute osteomyelitis, other specified site |
| 730.09 | Acute osteomyelitis, multiple sites |
| 730.20 | Osteomyelitis, site unspecified |
| 730.28 | Osteomyelitis, other specified site |
| 730.29 | Osteomyelitis, multiple sites |
| 730.30 | Periostitis, site unspecified |
| 730.38 | Periostitis, other specified site |
| 730.39 | Periostitis, multiple sites |
| 730.80 | Other infections involving bone in diseases classified elsewhere, site unspecified |
| 730.88 | Other infections involving bone in diseases classified elsewhere, other specified site |
| 730.89 | Other infections involving bone in diseases classified elsewhere, multiple sites |
| 730.90 | Unspecified infection of bone, site unspecified |
| 730.98 | Unspecified infection of bone, other specified site |
| 730.99 | Unspecified infection of bone, multiple sites |
| 785.52 | Septic shock |
| 790.7 | Bacteremia |
| 875.0 | Open wound into thoracic cavity without complication |
| 879.8 | Open wounds without mention of complications |
| 879.9 | Open wounds, unspecified, complicated |
| 891.0 | Open wound of leg without mention of complication |
| 891.1 | Open wound of leg with complication |
| 996.60 | Infection and inflammatory reaction due to unspecified device, implant |
| 996.61 | Infection and inflammatory reaction due to cardiac device, implant |
| 996.62 | Infection and inflammatory reaction due to vascular device, implant |
| 996.71 | Other complications due to heart valve prosthesis |
| 998.31 | Disruption of internal operation wound |
| 998.32 | Disruption of external operation wound |
| 998.51 | Infected postoperative seroma |
| 998.83 | Nonhealing surgical wound |
| 998.9 | Unspecified complication of procedure, not otherwise specified |
| CPT | |
| 10060 | Incision and drainage of abscess (eg, carbuncle, suppurative hidradenitis, cutaneous or subcutaneous abscess, cyst, furuncle, or paronychia); simple or single |
| 10061 | Incision and drainage of abscess (eg, carbuncle, suppurative hidradenitis, cutaneous or subcutaneous abscess, cyst, furuncle, or paronychia); complicated or multiple |

TABLE 1 (*Continued*)

| Code | Code text |
|---|---|
| 10140 | Incision and drainage of hematoma, seroma, or fluid collection |
| 10160 | Puncture aspiration of abscess, hematoma, bulla, or cyst |
| 10180 | Incision and drainage, complex, postoperative wound infection |
| 11010 | Debridement, including removal of foreign material associated with open fractures and/or dislocation; skin and subcutaneous tissues |
| 11040 | Debridement, skin, partial thickness |
| 11041 | Debridement, skin, full thickness |
| 11042 | Debridement, skin and subcutaneous tissue |
| 11043 | Debridement, skin, subcutaneous tissue, and muscle |
| 11044 | Debridement, skin, subcutaneous tissue, muscle, and bone |
| 12020 | Treatment of superficial wound dehiscence; simple closure |
| 12021 | Treatment of superficial wound dehiscence; with packing |
| 13160 | Secondary closure of surgical wound or dehiscence, extensive or complicated |
| 20000 | Incision of soft tissue abscess, superficial |
| 20005 | Incision of soft tissue abscess, deep |
| 39000 | Mediastinotomy with exploration, drainage, removal of foreign body or biopsy; cervical approach |
| 39010 | Mediastinotomy with exploration, drainage, removal of foreign body or biopsy; transthoracic approach |

rank a small number of Massachusetts hospitals by coronary artery bypass grafting (CABG) SSI rates[23] and demonstrated that this methodology can be implemented by payers.[24] We now evaluate the ability of Medicare claims data to rank US hospitals by their SSI rates after CABG. Applicability of claims data for this purpose would be an important example of the secondary use of routinely collected health information to improve the quality of care and patient safety.

## METHODS

This was a 3-phase study. First, we used a claims-based algorithm based on prior work[23,24] and piloted it in 5 hospitals to assess the relative sensitivity of routine surveillance and the algorithm. Second, on the basis of these results, we modified the algorithm and applied it to 2005 Medicare claims, ranking hospitals into deciles based on case mix–adjusted claims-based SSI rates. Third, we performed chart reviews of a sample of cases in the best- and worst-performing deciles to assess claims-based performance characteristics.

### Participating Organizations and Roles

The study was performed by the CDC Prevention Epicenters,[25] led by the epicenter based at Harvard's Department of Population Medicine, in collaboration with the Oklahoma Foundation for Medical Quality (OFMQ) acting in its capacity as a national hospital quality resource center for Medicare's Quality Improvement Organization Program. With the exception of the chart reviews for the national validation, OFMQ maintained possession of all information containing hospital identifiers or individual-level data, using computer programs developed jointly with investigators.

This study was conducted through an interagency agreement between CMS and CDC. Institutional Review Board approval was received at all participating CDC Prevention Epicenter sites.

### Phase 1: Comparing a Claims-Based Algorithm for CABG SSI Detection with Routine Surveillance

We applied a claims-based algorithm based on prior work[23,24] to Medicare claims from 5 CDC Prevention Epicenter hospitals. CMS claims were used to identify Medicare patients who had CABG procedures in 2005 (ICD-9-CM 36.10–36.17, 36.19, 36.2). Members of Medicare Advantage plans were excluded because claims are not available; reimbursement in these plans is not based on submitted claims. Repeat CABG procedures within 60 days were excluded.

SSIs were suspected if the algorithm identified patients with any of an extensive set of diagnostic (ICD-9) or procedure (ICD-9, CPT) codes occurring within 60 days after CABG.[23,24] A 60-day window was selected to maximize the number of CABG procedures evaluated in the available data set. Although hospitals often track SSIs for 1 year after CABG due to the presence of sternal wires, the 60-day window accounts for the majority of SSIs. For most surgeries, CDC SSI criteria require symptoms to begin within 30 days after surgery. We used 60 days to account for the fact that patients may seek care several weeks after the onset of symptoms.

CDC SSI criteria[26] were applied to the medical records of these patients and any additional Medicare patients with SSI identified through routine surveillance based on records from hospital infection prevention programs. On the basis of these results, the algorithm was refined by eliminating codes consistently identifying other postsurgical events while failing to identify SSIs.

The performance of the revised claims-based algorithm was compared with routine infection control surveillance by comparing ($\chi^2$) the fraction of chart review–confirmed cases iden-

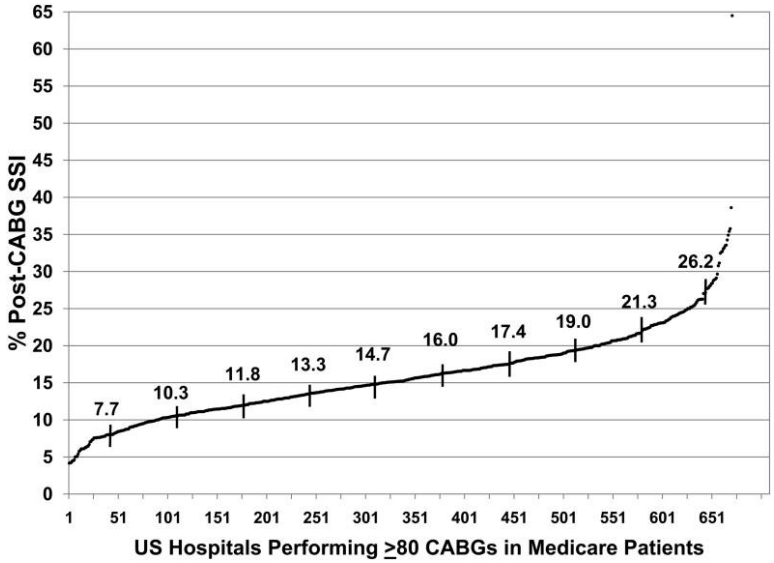


FIGURE 1. Unadjusted hospital-specific coronary artery bypass grafting (CABG) rates of occurrence of surgical site infection (SSI) codes by rank order for all 671 US hospitals performing at least 80 CABGs in Medicare patients. Bar markers indicate median values within a decile.

tified by each method divided by the total chart-confirmed cases by either method.

### Phase 2: Applying the Algorithm to the National Medicare Population to Rank US Hospitals

The algorithm was applied to a 2005 Medicare data set including all non-managed-care Medicare patients who underwent CABG procedures in US hospitals performing at least 80 annual CABG procedures in this population. The restriction to higher-volume institutions was made to focus on hospitals whose rates would not be unduly influenced by the detection or failure to detect a small number of infections. Hospital-specific unadjusted claims-based SSI rates were calculated.

We fit a logistic regression predicting claims-based SSI per CABG. To adjust for case mix, the model included age, sex, open or minimally invasive surgery, and the Romano score (an adaptation of the Charlson index, an ICD-9-based comorbidity score including 19 conditions evaluated in the year before surgery). The Romano score has been shown to perform best in adjusting for comorbidity in claims data and predicts mortality in Medicare patients.[22] Clustering within hospital was accounted for by including a random intercept and using generalized linear mixed models (GLMMs).[27] Hospital-specific SSI probabilities, including the predicted random effects, were adjusted for case mix and Medicare CABG volume. Hospitals were ranked by deciles of these SSI probabilities. All analyses were performed in SAS, version 9.1.

### Phase 3: Validation of Ranking in Extreme Deciles

We randomly selected for review 750 patients identified by the claims-based algorithm as having a code suggestive of SSI whose CABG was performed in a hospital in the best and worst deciles for adjusted SSI risk (1,500 patients total). Charts were requested from hospitals and outpatient clinics where an SSI claim code had been filed.

Charts with claims occurring on the day of surgery and those related to home health visits were excluded. Charts from all other visit types were requested, and all received charts were reviewed for post-CABG SSI.

We compared patient characteristics among those for whom charts were received or not received using $\chi^2$ tests. The $\chi^2$ tests were also used to compare the proportion of patients with any received record who had a confirmed SSI among best- and worst-decile hospitals. SSIs were described by location (sternal/donor site) and CDC-defined depth (superficial incisional/deep incisional/organ space).

Finally, we performed a case-control study to assess whether having a CABG performed in a worst- versus best-decile hospital was associated with higher risk of confirmed SSI. Cases were defined as patients with codes suggestive of SSIs and chart-confirmed SSIs. Controls were defined as the collection of 3 groups. The first group included patients with codes suggestive of SSI whose medical records revealed no SSI. The second group included patients selected for chart review whose medical records were not returned. This group assumes that none of the charts that failed to be returned would have confirmed SSI, a conservative assumption. The third group was a random sample of same-decile patients with no codes suggestive of SSI. This group was selected in proportion to the fraction of patients with an SSI code who were chosen for chart review. This group was included among the controls under the assumption that none of them had an SSI. The data analysis was based on a GLMM that was fit to

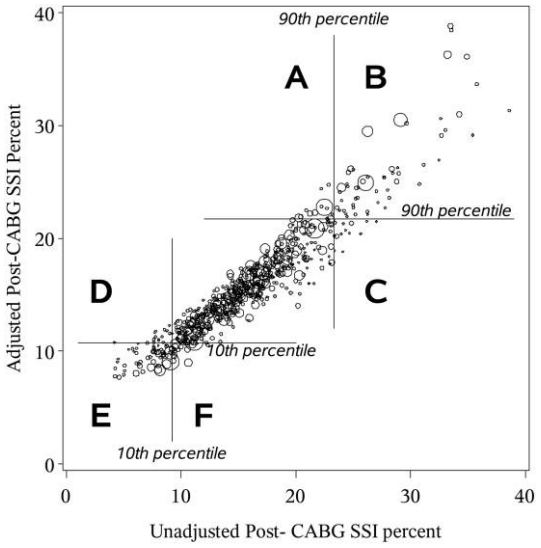


FIGURE 2. Plot of hospitals based on hospital-specific percents of Medicare patients who had surgical site infection (SSI) codes following coronary artery bypass grafting (CABG) procedures. Raw percents are compared with percents adjusted for age, sex, and comorbidities. Each hospital is depicted as a circle whose size reflects the number of patients. Decile markers (*lines*) are provided for best and worst deciles for raw and adjusted SSI percents. Hospitals ranked in *B* (55 hospitals) and *E* (53 hospitals) have raw and adjusted SSI percents located in the same decile (best or worst). Hospitals ranked in *C* (12 hospitals) have an unadjusted percent that places them in the worst decile, but their adjusted percentile places them out of the worst decile. Hospitals ranked in *A* (12 hospitals) have an unadjusted SSI percent that places them above the worst decile, but their adjusted percent places them to the worst decile. Likewise, hospitals in *D* (15 hospitals) would be included in the best decile with unadjusted but not adjusted percent, and *F* (15 hospitals) includes hospitals with adjusted but not unadjusted percents in the best decile. One hospital with unadjusted 64% SSI was excluded from the plot but would have appeared in *B*.

estimate the odds ratio of being a case in the best- versus worst-decile hospital, adjusted for age, sex, minimally invasive CABG, and comorbidity score and accounting for clustering by hospital.

## RESULTS

### Phase 1: Comparing the Claims-Based Algorithm with Routine Hospital Surveillance

The 5 hospitals performed 1,102 CABGs among Medicare beneficiaries in 2005 (average, 220; range, 87–340). On the basis of the final algorithm, 12% ($N = 128$) of patients (hospital range, 9%–16%) had an SSI code that resulted in chart review. Among patients with SSI codes, chart review confirmed SSI in 36% ($N = 48$; hospital range, 15%–62%). The claims-based diagnostic and procedure codes in the final algorithm are found in Table 1.

Using chart-confirmed SSI of patients identified through claims, routine surveillance, or both, we found that the sensitivity of claims-based surveillance was significantly higher than that of routine surveillance ($P < .001$). The claims-based algorithm identified all but 2 SSIs found by hospital infection prevention programs, resulting in 96% (48/50) sensitivity (range, 86%–100%) for SSI detection. In contrast, hospital routine surveillance missed 26 patients with confirmed SSI, resulting in a 48% (24/50) sensitivity for SSI (range, 14%–100%). The majority of cases missed by infection prevention programs involved SSIs that met CDC criteria but did not have a microbiology culture.

### Phase 2: Claims-Based Ranking of US Hospitals by SSI Rates

There were 114,586 CABG procedures among fee-for-service Medicare beneficiaries during 2005 at 671 hospitals that performed at least 80 CABG procedures (median, 132; range, 80–822). The median proportion of patients with diabetes across hospitals was 44%, with 9% end-stage renal disease and 63% vascular disease. The median Romano score was 5, with only 6% of patients with a score of 0.

Across hospitals, the unadjusted percent of patients with codes suggestive of SSI ranged from 4.2% to 64.5% (Figure 1). The percent of patients with codes suggestive of SSI across all surgeries performed in the best-decile hospitals (7.8% [963/12,313]) was significantly lower than in the worst-decile hospitals (25.3% [2,824/11,146]; $P < .001$). Unadjusted hospital-specific percent of patients with codes suggestive of SSI are plotted against adjusted percents in Figure 2.

Adjustment resulted in 8% (54/671) of hospitals moving into or out of the best and worst deciles. In the worst decile, 55 (82%) hospitals remained there after adjustment; for the best decile, this was the case for 53 (79%) hospitals. Characteristics of patients with and without SSI codes are provided in Table 2 for hospitals in the best and worst deciles, after adjustment.

### Phase 3: Chart Review Validation

Of the 1,500 patients randomly selected for chart review, 114 patients were excluded because their codes suggestive of SSI were limited to home health claims ($N = 83$) or claims on the day of surgery ($N = 31$). The remaining 716 patients from best-decile hospitals and 670 patients from worst-decile hospitals had medical records requested from all visits with a code suggestive of SSI. We requested 2,717 records, representing 4,181 claims with SSI codes. We received at least 1 requested chart for 71% of patients.

Inpatient charts were most consistently returned (97%), followed by outpatient visits listed by clinic name and address (90%), nursing homes (70%), and then outpatient visits listed by the physician's name and address (35%). The low return rate among physician office claims was because physicians often had several offices but listed only 1 address for claims.

TABLE 2. Characteristics of Patients in Hospitals with the Highest and Lowest Percentages of Patients with a Surgical Site Infection (SSI) Diagnosis or Procedure Code

| | Best decile | | Worst decile | |
|---|---|---|---|---|
| | Patients with an SSI code | Patients without an SSI code | Patients with an SSI code | Patients without an SSI code |
| No. of cases[a] | 958 | 11,349 | 2,747 | 8,321 |
| Age, years | | | | |
| Overall mean (SD) | 74.9 (5.8) | 74.4 (5.8) | 75.3 (6.1) | 74.8 (6.1) |
| 65–74, % | 54 | 56 | 49 | 53 |
| 75–84, % | 41 | 41 | 45 | 42 |
| 85+, % | 5 | 4 | 6 | 5 |
| Male, % | 59 | 66 | 60 | 68 |
| Minimally invasive, % | 43 | 37 | 35 | 27 |
| Romano score | | | | |
| Overall mean (SD) | 5.1 (2.9) | 3.5 (2.6) | 5.2 (2.9) | 3.9 (2.8) |
| Low (0), % | 6 | 11 | 6 | 10 |
| Medium (1–4), % | 45 | 57 | 43 | 54 |
| High (5+), % | 49 | 32 | 51 | 36 |

[a] Note that the total number of patients in the best and the worst decile are not the same because deciles are based on hospital-specific SSI rates from claims data. Numbers reflect the combined coronary artery bypass grafting surgical volume of hospitals in the best and worst decile by SSI rates.

Thus, many requests were returned because no patient with the provided name was seen at that clinic.

Characteristics of patients with reviewed records are provided in Table 2. Descriptors were similar in all aspects among those with and without records available for review.

Once a claim identified a potential SSI, the decile (best vs worst) had little impact on the probability that SSI would be confirmed by chart review: 41% (221/538) of patients with a code suggestive of SSI were confirmed in the best decile and 38% (167/442) in the worst decile ($P = .3$; Table 3). Thus, while best-decile hospitals had fewer patients with a code suggestive of SSI than did worst-decile hospitals, once identified, the confirmation fraction was similar.

The proportions of chart-confirmed SSIs between best and worst deciles were statistically similar across inpatient claims (29% [158/538] vs 26% [114/442]; $P = .6$) and outpatient claims (21% [113/538] vs 21% [95/442]; $P = .3$) and whether SSIs were superficial incisional (19% [104/538] vs 19% [83/442]; $P = .9$), deep incisional (12% [64/538] vs 11% [48/442]; $P = 1.0$), or organ space (10% [53/538] vs 8% [36/442]; $P = .6$). Confirmation of sternal infections was also statistically similar (27% [114/442] vs 22% [96/442]; $P = .2$), but best-decile hospitals had significantly fewer confirmed donor site infections compared with worst-decile hospitals (16% [85/538] vs 19% [83/442]; $P = .03$).

In the case-control analysis, 3.2% of subjects in best-decile hospitals and 9.4% of patients undergoing CABG in worst-decile hospitals experienced chart-confirmed SSI. When we adjusted for age, sex, comorbidities, and clustering within hospital, patients having a CABG performed in a worst-decile hospital compared with a best-decile hospital had a 2.7-fold higher odds of confirmed post-CABG SSI (Table 4). Female sex and increasing comorbidity score were also associated with SSI. Older age was associated with a lower risk of SSI.

## DISCUSSION

Our goals were to compare the performance of a claims-based algorithm using routinely collected diagnosis and procedure codes with that of typical hospital surveillance and to determine whether these codes were a sufficient surrogate measure of SSI to identify hospitals likely to have high (or low) rates of SSI after CABG. This is thus an example of the secondary use of routinely electronic health data to improve healthcare quality. The intended use of this approach is to perform routine periodic assessment of very large claims data sets to identify institutions that merit additional evaluation. Medicare claims are currently the largest such data set, but others for which this approach may be considered include large insurers and multipayer databases that are being developed.

Medicare claims identified twice as many patients with chart-confirmed post-CABG SSI than did routine hospital-based surveillance by infection control and prevention programs in 5 academic health centers. Infections that occurred after discharge and those lacking microbiologic cultures contributed to the extra yield. Nationally, Medicare claims also identified a group of hospitals with high aggregate confirmed post-CABG SSI rates.

Since the proportion of patients with a claim suggestive of SSI was proportional to the rate of chart-confirmed SSI, routine evaluation of diagnosis and procedure codes may be a useful screening method for CMS and other insurers to identify hospitals that merit additional evaluation based on automated analysis of centralized insurer data. Our findings do

TABLE 3. Characteristics of Patients with Medical Records Reviewed to Confirm Surgical Site Infections (SSIs)

| | Best decile | Worst decile |
|---|---|---|
| *N* | 538 | 442 |
| Age, years | | |
| Overall mean (SD) | 74.3 (5.7) | 74.5 (6.0) |
| 65–74, % | 54 | 53 |
| 75–84, % | 41 | 42 |
| 85+, % | 5 | 5 |
| Male, % | 58 | 60 |
| Minimally invasive, % | 43 | 34 |
| Romano score | | |
| Overall mean (SD) | 4.7 (2.8) | 4.8 (3.0) |
| Low (0), % | 6 | 7 |
| Medium (1–4), % | 47 | 41 |
| High (5+), % | 48 | 52 |
| Chart-confirmed SSI, % | 41 | 38 |
| Inpatient | 29 | 26 |
| Outpatient | 21 | 21 |
| Nursing home | 1 | 1 |
| Sternal SSI, % | 27 | 22 |
| Superficial | 12 | 10 |
| Deep | 5 | 4 |
| Organ space | 10 | 8 |
| Donor SSI, % | 16 | 19 |
| Superficial | 9 | 11 |
| Deep | 7 | 8 |
| Organ space | 0 | 0 |

not imply that every hospital with a high proportion of SSI codes has a high rate of confirmed SSI. Targeted evaluation of hospitals with a high proportion of codes would be needed to confirm actual rates of SSI.[28] It will also be important to determine whether additional case mix adjustment is also warranted, using measures not available in claims data, such as ventricular function and functional status.

Use of national data sets to identify outlier hospitals would allow quality improvement organizations and others to direct evaluation and quality improvement activities toward hospitals in greatest need of evaluation and assistance. This use is highly consistent with the current emphasis on meaningful use of electronic health data by CMS and the Office of the National Coordinator of Health Information Technology, namely, "capturing health information in a coded format, using that information to track key clinical conditions, communicating that information for care coordination purposes, and initiating the reporting of clinical quality measures and public health information."[29]

This approach can also be used by insurers or states to assess hospital post-CABG SSI rates as previously shown;[19,20] such methods would be especially powerful if they combined data across payers. Claims-based evaluations could identify best-practice hospitals that have consistently low SSI rates, perhaps allowing identification of practices that account for low SSI rates.

The use of routinely collected electronic health information has several advantages over traditional methods, including improved adjustment for case mix, conservation of scarce infection preventionist resources, and minimizing variability in surveillance methods. Currently, SSI surveillance is not standardized and often misses postdischarge events and SSIs lacking culture data.

While the use of claims has several advantages, this study has important limitations. First, we validated only the ability of this algorithm to distinguish hospitals in the extreme (best or worst) deciles. We also chose not to review home health or day-of-surgery codes, although we note that a higher proportion of these codes were found in the worst-decile hospitals. Had these confirmed SSIs, it would have only strengthened our findings. Second, this approach is not helpful for evaluating hospitals with low Medicare procedure volumes. We do not know whether our threshold of 80 procedures per year is optimal. It will be worthwhile to assess the applicability of this approach to hospitals that perform fewer procedures.

Third, claims data depend on hospital coding practices. For this reason, we selected an extensive set of codes to prevent "gaming the system" by choosing alternative codes that described the same disease process. However, to the extent that the SSI codes become known, it will be possible for clinicians or institutions to avoid their use. Fourth, while our case mix adjustment method included more factors than is standard for SSI reporting, it omitted important risk factors, such as obesity. As such information becomes more widely available in electronic medical records, it should be incorporated into standard case mix adjustment. Until then, it will be necessary to take such factors into account during the evaluation of outlier hospitals. Finally, our results are limited by partial return of requested charts for medical record validation of SSIs. Since we assumed that all those without returned charts had no SSIs, we underestimated the ability of claims to detect post-CABG SSIs.

We have no information about important aspects of this ranking system, especially whether hospitals' rankings persist

TABLE 4. Predictors of Confirmed Surgical Site Infection (SSI) after Coronary Artery Bypass Grafting (CABG)

| | Odds ratio (confidence interval) | *P* value |
|---|---|---|
| CABG performed in worst- vs best-decile hospital | 2.7 (2.2, 3.3) | <.001 |
| Age, years | | .001 |
| 65–74 | 1.0 | |
| 75–84 | 0.7 (0.5, 0.8) | |
| 85+ | 0.6 (0.4, 1.0) | |
| Female | 1.7 (1.4, 2.1) | <.001 |
| Open vs minimally invasive | 1.0 (0.8, 1.2) | .8 |
| Romano score | | <.001 |
| Low (0) | 1.0 | |
| Medium (1–4) | 1.4 (0.9, 2.2) | |
| High (5+) | 2.5 (1.6, 4.0) | |

year to year and whether this approach is applicable to other surgeries.

In conclusion, routinely collected electronic claims can identify hospitals with unusually high post-CABG SSI risks. This method is more sensitive and efficient than current hospital-based surveillance methods. It is an example of the meaningful use of electronic health data to support national improvements in healthcare quality and patient safety.

## ACKNOWLEDGMENTS

S.S.H. had access to the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. The authors assume full responsibility for the accuracy and completeness of the ideas presented (4-999-OK-1110).

*Financial support.* This study was funded by the CDC Prevention Epicenters Program CCU115079 (Platt) and under contract HHSM-500-2006-OK0030, entitled "Utilization and Quality Control Peer Review Organization for the State Oklahoma, Sponsored by the Centers for Medicare and Medicaid Services, Department of Health and Human Services." The funders did not participate in study design, study conduct, analysis, data interpretation, or manuscript preparation.

*Potential conflicts of interest.* R.P. has had active research grants in the past 3 years from Sanofi-Pasteur, GlaxoSmithKline, and Pifzer Pharmaceuticals. D.S.Y. has received research support from Sage Products. V.J.F. has been a consultant for Steris and Verimetrix and a member of the Speakers Bureau for Pfizer, Merck, and Cubist Pharmaceuticals in the past 3 years.

Address correspondence to Susan S. Huang, MD, MPH, University of California Irvine School of Medicine, Division of Infectious Diseases, 101 City Drive South, City Tower, Suite 400, ZC 4081, Orange, CA 92868-3217 (sshuang@uci.edu).

## REFERENCES

1. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care–associated infections and deaths in U.S. hospitals, 2002. *Public Health Rep* 2007;122(2):160–166.
2. Horan TC, Culver DH, Gaynes RP, Jarvis WR, Edwards JR, Reid CR. Nosocomial infections in surgical patients in the United States, January 1986–June 1992: National Nosocomial Infections Surveillance (NNIS) System. *Infect Control Hosp Epidemiol* 1993; 14(2):73–80.
3. Jarvis WR. Benchmarking for prevention: the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance (NNIS) system experience. *Infection* 2003;31(suppl 2):44–48.
4. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. *Am J Epidemiol* 1985;121(2):182–205.
5. Medicare Quality Improvement Community. *Surgical care improvement project.* http://www.qualitynet.org/dcs/ContentServer?cid=1192804535739&pagename=QnetPublic%2FPage%2FQnetTier3&c=Page. Accessed June 8, 2011.
6. Joint Commission. *Performance measurement initiatives: Surgical Care Improvement Project core measure set.* http://jointcommission.org/surgical_care_improvement_project/. Accessed June 8, 2011.
7. Centers for Disease Control and Prevention. *National Healthcare Safety Network: surgical site infection (SSI) event.* http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf. Accessed October 22, 2010.
8. Institute for Healthcare Improvement. *Saving Lives Web and action program: preventing surgical site infections.* http://www.ihi.org/IHI/Programs/AudioAndWebPrograms/WebAction_SSI.htm. Accessed October 22, 2010.
9. Bratzler DW, Hunt DR. The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery. *Clin Infect Dis* 2006; 43:322–330.
10. Avato JL, Lai KK. Impact of postdischarge surveillance on surgical-site infection rates for coronary artery bypass procedures. *Infect Control Hosp Epidemiol* 2002;23(7):364–367.
11. Sands K, Vineyard G, Platt R. Surgical site infections occurring after hospital discharge. *J Infect Dis* 1996;173(4):963–970.
12. Petherick ES, Dalton JE, Moore PJ, Cullum N. Methods for identifying surgical wound infection after discharge from hospital: a systematic review. *BMC Infect Dis* 2006;6:170.
13. Tanner J, Khan D, Aplin C, Ball J, Thomas M, Bankart J. Postdischarge surveillance to identify colorectal surgical site infection rates and related costs. *J Hosp Infect* 2009;72(3):243–250.
14. Holbrook KF, Nottebart VF, Hameed SR, Platt R. Automated postdischarge surveillance for postpartum and neonatal nosocomial infections. *Am J Med* 1991; 91:125S–130S.
15. Fanning C, Johnston BI, Macdonald S, LeFort-Jost S, Dockerty E. Postdischarge surgical site infection surveillance. *Can J Infect Control* 1995;10(3):75–79.
16. Taylor EW, Duffy K, Lee K, et al. Telephone call contact for post-discharge surveillance of surgical site infections: a pilot, methodological study. *J Hosp Infect* 2003;55(1):8–13.
17. Platt R. Toward better benchmarking. *Infect Control Hosp Epidemiol* 2005;26:433–434.
18. Platt R, Yokoe DS, Sands KE; and the CDC Eastern Massachusetts Prevention Epicenter Investigators. Automated methods for surveillance of surgical site infections. *Emerg Infect Dis* 2001; 7(2):212–216.
19. Anderson DJ, Chen LF, Sexton DJ, Kaye KS. Complex surgical site infections and the devilish details of risk adjustment: important implications for public reporting. *Infect Control Hosp Epidemiol* 2008;29(10):941–946.
20. Giles KA, Hamdan AD, Pomposelli FB, Wyers MC, Siracuse JJ, Schermerhorn ML. Body mass index: surgical site infections and mortality after lower extremity bypass from the National Surgical Quality Improvement Program 2005–2007. *Ann Vasc Surg* 2009;24(1):48.
21. Schneeweiss S, Seeger JD, Maclure M, Wang PS, Avorn J, Glynn RJ. Performance of comorbidity scores to control for confounding in epidemiologic studies. *Am J Epidemiol* 2001;154(9): 854–864.
22. Schneeweiss S, Wang PS, Avorn J, Glynn RJ. Improved comorbidity adjustment for predicting mortality in Medicare populations. *Health Serv Res* 2003;38(4):1103–1120.
23. Platt R, Kleinman K, Thompson K, et al. Using automated health plan data to assess infection risk from coronary artery bypass surgery. *Emerg Infect Dis* 2002;8(12):1433–1441.
24. Huang SS, Livingston JM, Rawson NS, Schmaltz S, Platt R. Developing algorithms for healthcare insurers to systematically

monitor surgical site infection rates. *BMC Med Res Methodol* 2007;7:20.
25. Centers for Disease Control and Prevention. *Prevention Epicenters Program.* http://www.cdc.gov/HAI/epiCenters/what-R-epicenters.html. Accessed June 8, 2011.
26. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care–associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control* 2008;36:309–332.
27. Breslow NE, Clayton DG. Approximate inference in generalized linear mixed models. *J Am Stat Assoc* 1993;88(421):9–25.
28. Yokoe DS, Noskin GA, Cunningham SM, et al. Enhanced identification of postoperative infections among inpatients. *Emerg Infect Dis* 2004;10(11):1924–1930.
29. Centers for Medicare and Medicaid Services. *CMS proposes definition of meaningful use of certified electronic health records (EHR) technology.* http://www.cms.gov/apps/media/press/factsheet.asp?Counter=3564. Accessed June 27, 2010.