Leveraging Electronic Medical Records in the Surveillance of Surgical Site Infections in a Total Joint Replacement Population

Maria C.S. Inacio MS • Elizabeth W. Paxton MA • Yuexin Chen BS • Jessica Harris RD, MS • Enid Eck RN, MPH • Sue Barnes RN, BSN, CIC • Robert S. Namba MD

Abstract:

Current Center for Disease Control and Prevention (CDC) guidelines for the prevention of surgical site infection (SSI) do not offer recommendations on post operative SSI surveillance methods. At a large health maintenance organization, the surveillance of Total Joint Replacement (TJR) surgeries' SSIs were historically performed by reviewing all medical charts. A hybrid electronic SSI screening algorithm that leverages electronic medical records and a TJR registry post-operative follow up system sensitivity was tested in a large population of TJRs. Chart review burden was also evaluated. Using ICD9 diagnostic and procedural codes for infection, wound complications, cellulitis, procedures related to infections, and surgeon reported complications captured at the point of care, we screened each TJR procedure between 01/2006 and 12/2008 for one year post-operative. Experts in TJR complications then reviewed the flagged charts to confirm SSI. SSIs identified using the electronic screening algorithm were compared to SSIs identified using traditional methodology. Positive predictive, negative predictive, specificity, and sensitivity values were calculated for the overall algorithm and absolute reduction of number of chart reviews was calculated. The algorithm identified 4001 (9.5%) possible infections in our TJR population of 42173. Of the possible cases only 440 (11.0%) were true SSIs. The overall algorithm sensitivity was 97.8% with 91.5% specificity. While this algorithm may still not be specific enough to hone in on the cases with new SSIs related to TJR using only electronic sources we created a 97.8% sensitive algorithm and reduced the chart review work burden by 90.5%.

Background:

Total Knee (TKR) and Total Hip (THR) Replacement are high volume, costly procedures. TJR procedures have reported surgical site infection (SSI) rates of 0.5-6%.[1-6] SSIs following TJR procedures have devastating consequences for the health of the patient and can cost an estimated $30,000-$50,000 for a revision procedure, and over $96,000 for required care over the course of a year after infection.[6-10]

Surveillance of TJR SSI is recommended by the CDC and mandated by the hospital accrediting body The Joint Commission. However, there is not a standard protocol for SSI surveillance case identification.[11] Over 11 years after the CDC publication on the Guideline for Previsions of Surgical Site Infection, 1999,[11] most SSI case identification methods reported in the literature still consist of direct observation by surgeons,[12, 13] indirect observation by Infection Control Professionals (ICP),[14, 15] electronic surveillance using administrative, pharmacy, and claims databases,[16-19] and surveying of patients and physicians after procedure.[12]

Within our integrated health care system, which serves 8.6 million members in eight U.S. regions, TJR SSI surveillance consisted of traditional manual review of all total joint patients medical charts according to CDC guidelines. With 17000 TJRs performed each year, this traditional method was time consuming and resource intensive. As a result, we developed a more efficient screening algorithm to track TJR SSIs.

The purpose of this study is to describe the development and validation of this electronic TJR SSI screening algorithm. This study also determines the impact of application of this algorithm on the volume of chart review required for TJR SSI surveillance within a large HMO.

Methods:

Study Design:

A SSI screening algorithm was developed using a combination of registry surveillance and electronic health record (EHR) review. A validation study was performed to test the algorithm on TJRs performed at a large HMO between 01/2006 and 12/2008.

Data Sources:

Within our organization, traditional SSI surveillance consists of standard indirect observation surveillance with ICPs manually reviewing all TJR patient charts for up to one year post-operatively. SSI cases, identified using this traditional method, were used as the gold standard for validation of our case identification algorithm.

The TJR Registry captures demographics, surgical techniques, implant characteristics, and outcomes (e.g., revisions, infections) for all TJR performed within our system.[20, 21] For this study, we used the post-operative form which collects information on the presence of wound complications, wound dehiscence, superficial infection, deep infection, cellulitis, and stitch abscess as one method to identify SSI for our hybrid electronic screening algorithm, referred to as TJR Registry reported complications in our report.

The TJR Registry was also used to identify all TJR cases performed in California during the study period. All cases were identified using the ICD 9-CM procedure codes

Electronic Screening of ICD 9-CM Diagnostic and Procedure Codes:

The second part of this algorithm consists of ICD 9-CM diagnostic and procedural codes identified from the orthopedic and infection control literature.[22-24] We also consulted local coding experts to identify additional codes for SSI detection. EHR inpatient activity, emergency room, urgent care, outpatient and ambulatory encounters for infection diagnosis, procedures for infection, and any of the possible registry reported complications were reviewed from 1 day after the procedure to 400 days post-operative. Cellulitis and wound diagnoses were screened up to 120 days post-operative.

EHR Chart Review of Flagged Cases:

The clinical content experts at the TJR registry who specialize in the content of TJR surgery and significant post-operative complications review all charts. The process of deciding whether flagged SSI cases are true positives involves review of all documentation available in the patients' EHR. Following chart review, CDC/NHSN guidelines for superficial and deep surgical site infections are applied to the findings.[25] If the criterion is met for either classification the appropriate infection type, date of infection, culture findings, signs or symptoms of infection, and treatment are recorded in the registry database.

Validation of TJR SSI Screening Algorithm:

We compared true positive cases identified by the hybrid algorithm with the SSIs identified by ICPs using the traditional indirect observation surveillance method.

Statistical Analysis:

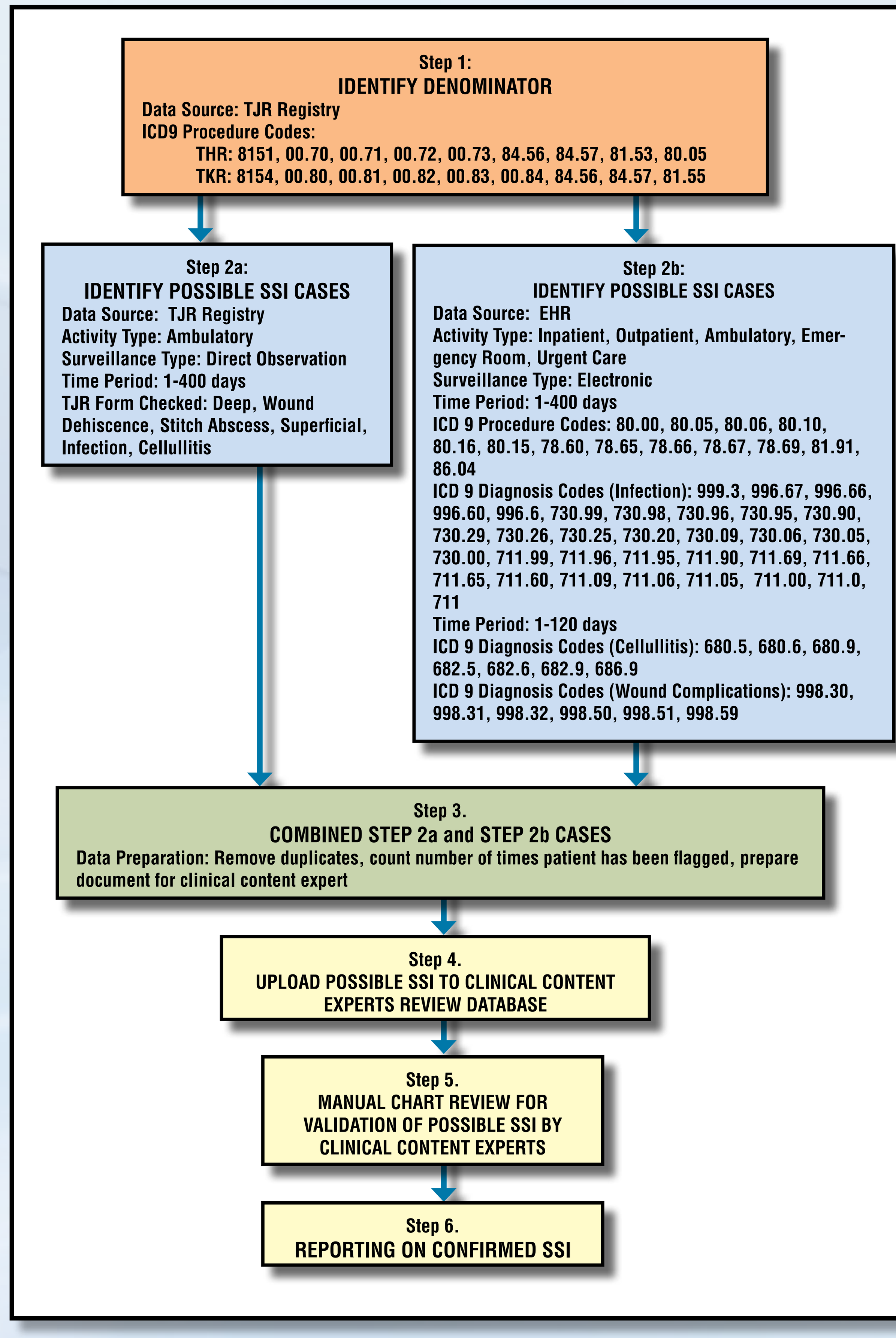
After review and categorization as true positives, false positives, false negatives, and true negatives, statistical analyses were performed. Positive predicted values (PPV), negative predicted values (NPV), specificity and sensitivity were calculated for each of the infection indicators the algorithm uses. Further stratification of the indicators, into the used hospital care setting (inpatient, outpatient, emergency care, or urgent care) or ambulatory care settings (office visits only) was also performed. Stratification by diagnosis type and whether it was identified using the EHR or registry component of the algorithm was also performed. Combinations of the indicators were also evaluated for possible increased predicted values and higher accuracy in algorithm prediction. All analyses were performed using SAS (Version 9.1.3, SAS Institute, Cary, NC, USA).

Results:

Between 01/2006 and 12/2008 there were 42173 TJR procedures performed at this organization. 13083 (31%) were primary THR, 1551 (3.7%) were revision THA, 25860 primary TKR (61.3%), and 1679 revision TKR (4.0%). The overall confirmed SSI rate for this population is 1.07 % (N=450), 0.69% (N=291) had a deep SSI, and 0.38% (N=159) had a superficial SSI. Revision procedures had the highest rate of infection, 2.8% (N=44) for THR and 1.9% (N=32) for TKR. Primary THR had the lowest rate of infection at 0.9% (N=117) followed by primary TKR at 1.0% (N=257).

Using the combined screening algorithm (including all the different indicator components) 4001 cases (9.5%) out of the 42173 procedures identified were flagged for review by the clinical content experts. This reduced the volume of ICP chart reviews by 38172 charts over the course of 3 years. Of the 4001 charts reviewed, 440 infections were confirmed. This represents an 11.0% PPV, 100.0% NPV, with 97.8% sensitivity and 91.5% specificity. There were 10 (2.2%) confirmed infections by the Infection Control Department that were not identified using the overall screening algorithm.

Figure 1. TJR Registry Hybrid Infection Screening Algorithm Process



The infection indicator of this algorithm with the highest sensitivity (86.9%) and PPV (16.7%) was whether the patient had any hospital activity; this included any visits to the emergency room, urgent care, inpatient care, or ambulatory care center. Cellulitis and stitch abscess reported to the registry were the indicators with the lowest sensitivity (both 0.9%) and lowest PPV (4.9% and 5.8% respectively). Specificity was consistently high for all infection indicators in the algorithm, ranging from 99.9% for wound diagnosis and deep infection reported to the registry to 95.3% for any hospital activity. Table 3 has PPVs, NPVs, specificity and sensitivity for each component of the algorithm. Any registry reported SSIs, which is the direct reporting portion surveillance of our algorithm had a low sensitivity level of 19.6%, but a high level of specificity (99.3%).

Table 3. True Positive, False Negative, False Positive, and True Negative Cases, and Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value of Overall Infection Screening Algorithm and Algorithm Components

	TP	FN	FP	TN	Sensitivity	Specificity	PPV	NPV
Overall Algorithm	440	10	3561	38162	97.8%	91.5%	11.0%	100.0%
Any Hospital Activity: inpatient, outpatient, emergency care, urgent care	391	59	1947	39776	86.9%	95.3%	16.7%	99.9%
Any Ambulatory Activity	287	163	1752	39971	63.8%	95.8%	14.1%	99.6%
Any Procedure Diagnosis	219	231	1204	40519	48.7%	97.1%	15.4%	99.4%
Infection Diagnosis: any location	322	128	1106	40617	71.6%	97.3%	22.5%	99.7%
Wound Diagnosis: any location	234	216	1019	40704	52.0%	97.6%	18.7%	99.5%
Cellullitis Diagnosis: any location	147	303	1439	40284	32.7%	96.6%	9.3%	99.3%
Infection Check: registry reported	79	371	132	41591	17.6%	99.7%	37.4%	99.1%
Deep Infection Check: registry reported	50	400	46	41677	11.1%	99.9%	52.1%	99.0%
Superficial Infection Check: registry reported	30	420	82	41641	6.7%	99.8%	26.8%	99.0%
Wound Diagnosis: registry reported	15	435	34	41689	3.3%	99.9%	30.6%	99.0%
Stitch Abscess Check: registry reported	4	446	65	41658	0.9%	99.8%	5.8%	98.9%
Cellullitis Diagnosis: registry reported	4	446	78	41645	0.9%	99.8%	4.9%	98.9%
Any Registry Reported	88	362	274	41449	19.6%	99.3%	24.3%	99.1%

TP=True Positive, FN=False Negative, FP=False Positive, TN=True Negative, PPV=Positive Predicted Value, NPV=Negative Predicted Value

Formulas used: PPV=TP/(TP+FP) NPV= TN/(TN+FN) Sensitivity=TP/(TP+FN) Specificity=TN/(FP+TN)

Discussion:

The hybrid algorithm presented in this study decreased the number of charts that are manually reviewed by our institution's ICPs for TJR SSI surveillance by 90.5%. This algorithm was efficient and cost effective with a high sensitivity and specificity of 97.8% and 91.5% respectively. This algorithm assured the review of all charts with possible complications while still reducing the volume of charts compared to the previous surveillance methodology.

Indirect observation of charts for SSI infection surveillance at our institution would require the review of as many as 4000 charts at just one location per year. Because of such challenge we decided to invest in developing an electronic screening method using both the EHR and TJR Registry available to us to screen possible cases of SSI that will then be confirmed by a group of experts. Our study found similar encouraging results as Patkar et al did in their study of identifying bacterial infections in rheumatoid arthritis patients using a combination of administrative codes and medical records chart review.[26] Most of the case finding determination for the surveillance of SSI debates the merits of electronic screening, however, most studies focus on the implementing a single system (i.e. using electronic screening alone) such as Stevenson et al, who found a PPV of only 14%-51% in their study,[27] or Platt et al who found a 58% PPV in their algorithm for coronary artery bypass surgery SSI,[28] or again Platt et al's general post-discharge SSI surveillance algorithm that has a 48% PPV.[29] Another limitation of case finding algorithms that use ICD 9 codes as their main search criteria, such as Caldwaller et al,[15] Olsen et al,[19] Bolon et al[30] use a small number of ICD 9 codes limiting the sensitivity of their algorithms. Using just one method to capture the SSI will decrease the surveillance sensitivity and using just a few codes to identify the SSI will certainly miss cases that can be coded with variant ICD 9 codes due to different coding behaviors and practices.

Because of the time required for indirect observation surveillance the cost can be prohibitive as well. In our organization over 17000 TJR procedures are performed annually, and reviewing all of these charts is estimated to take 8500 hours of labor. Given the standard compensation for ICPs and other indirect costs, we estimate that this can cost roughly $571,000 per year in our organization. Implementing our hybrid screening algorithm can decrease the number of charts by 90% and save over $514,000 per year.

This study has several strengths. It provides the final coding algorithm, optimal timeline for screening, and type of patient activity that was deemed of the highest sensitivity to capture all SSIs in our population. Another strength of our study is the large sample size, which allows estimating the PPV and NPV of several different components of our algorithm for this low incidence complication. Our algorithm also takes advantage of a large integrated healthcare system and therefore has the ability to capture SSIs during ambulatory, urgent care, and emergency room visits.[31] Finally, another strength is that this algorithm relies only on diagnostic and procedure codes to identify the SSI, excluding laboratory results and antibiotic prescriptions from the surveillance. Laboratory test screening were found to be redundant and antibiotic prescription greatly decreased the sensitivity of our algorithm as shown in other studies.[31]

A limitation of this algorithm is the misclassification of at least 10 cases into false negative. We investigated the reasons for the misclassification of these cases and found that two cases had not been ascertained because the infection reporting occurred during the hospital stay for the procedure. Seven cases were either diagnosed incorrectly for conditions such as hematomas, or procedures like draining, manipulation under anesthesia, or the time frame of our algorithm had been violated. The final case, had a superficial infection, was determined from the data from a skilled nursing facility where the patient resided post-operative and its data sources were not searched by our algorithm.

Conclusion:

This study described the development and assessment of a highly sensitive and specific case finding algorithm that takes advantage of an EHR system in a large health maintenance organization. This algorithm successfully reduced the number of charts to be reviewed to only 9.5% of the total number of cases performed in our organization. his hybrid algorithm in combination with clinical content experts' judgment provides a good alternative to the indirect surveillance methodology previously applied in our organization or pure electronic screening.

References:

1. Namba RS, Chen Y, Paxton EW, Slipchenko T, Fithian DC. Outcomes of routine use of antibiotic-loaded cement in primary total knee arthroplasty. J Arthroplasty. 2009;24(6 Suppl):44-7.
2. Barnes S, Salemi C, Fithian D, et al. An enhanced benchmark for prosthetic joint replacement infection rates. Am J Infect Control. 2006;34(10):669-72.
3. Lentino JR. Prosthetic joint infections: bane of orthopedists, challenge for infectious disease specialists. Clin Infect Dis. 2003;36(9):1157-61.
4. Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. J Bone Joint Surg Br. 2005;87(6):844-50.
5. Babkin Y, Raveh D, Lifschitz M, et al. Incidence and risk factors for surgical infection after total knee replacement. Scand J Infect Dis. 2007;39(10):890-5.
6. Bozic KJ, Ries MD. The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization. J Bone Joint Surg Am. 2005;87(8):1746-51.
7. Bozic KJ, Katz P, Cisternas M, Ono L, Ries MD, Showstack J. Hospital resource utilization for primary and revision total hip arthroplasty. J Bone Joint Surg Am. 2005;87(3):570-6.
8. Hebert CK, Williams RE, Levy RS, Barrack RL. Cost of treating an infected total knee replacement. Clin Orthop Relat Res. 1996(331):140-5.
9. Sculco TP. The economic impact of infected joint arthroplasty. Orthopedics. 1995;18(9):871-3.
10. Whitehouse JD, Friedman ND, Kirkland KB, Richardson WJ, Sexton DJ. The impact of surgical-site infections following orthopedic surgery at a community hospital and a university hospital: adverse quality of life, excess length of stay, and extra cost. Infect Control Hosp Epidemiol. 2002;23(4):183-9.
11. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol. 1999;20(4):250-78; quiz 79-80.
12. Reilly J, Noone A, Clift A, et al. A study of telephone screening and direct observation of surgical wound infections after discharge from hospital. J Bone Joint Surg Br. 2005;87(7):997-9.
13. Ferraz EM, Ferraz AA, Coelho HS, et al. Postdischarge surveillance for nosocomial wound infection: does judicious monitoring find cases? Am J Infect Control. 1995;23(5):290-4.
14. Huotari K, Agthe N, Lyytikainen O. Validation of surgical site infection surveillance in orthopedic procedures. Am J Infect Control. 2007;35(4):216-21.
15. Cadwallader HL, Toohey M, Linton S, Dyson A, Riley TV. A comparison of two methods for identifying surgical site infections following orthopaedic surgery. J Hosp Infect. 2001;48(4):261-6.
16. Baker C, Luce J, Chenoweth C, Friedman C. Comparison of case-finding methodologies for endometritis after cesarean section. Am J Infect Control. 1995;23(1):27-33.
17. Hirschhorn LR, Currier JS, Platt R. Electronic surveillance of antibiotic exposure and coded discharge diagnoses as indicators of postoperative infection and other quality assurance measures. Infect Control Hosp Epidemiol. 1993;14(1):21-8.
18. Chalfine A, Cauet D, Lin WC, et al. Highly sensitive and efficient computer-assisted system for routine surveillance for surgical site infection. Infect Control Hosp Epidemiol. 2006;27(8):794-801.
19. Olsen MA, Fraser VJ. Use of diagnosis codes and/or wound culture results for surveillance of surgical site infection after mastectomy and breast reconstruction. Infect Control Hosp Epidemiol.31(5):544-7.
20. Paxton E, Inacio M, Slipchenko T, Fithian D. The Kaiser Permanente National Total Joint Replacement Registry. The Permanente Journal. 2008;12(3):12-6.
21. Paxton EW, Inacio MC, Khatod M, Yue EJ, Namba RS. Kaiser Permanente National Total Joint Replacement Registry: Aligning Operations With Information Technology. Clin Orthop Relat Res. 2010;Jul 20. [Epub ahead of print].
22. Ong KL, Kurtz SM, Lau E, Bozic KJ, Berry DJ, Parvizi J. Prosthetic joint infection risk after total hip arthroplasty in the Medicare population. J Arthroplasty. 2009;24(6 Suppl):105-9.
23. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. J Bone Joint Surg Am. 2004;86-A(9):1909-16.
24. Miner AL, Losina E, Katz JN, Fossel AH, Platt R. Deep infection after total knee replacement: impact of laminar airflow systems and body exhaust suits in the modern operating room. Infect Control Hosp Epidemiol. 2007;28(2):222-6.
25. 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(5):309-32.
26. Patkar NM, Curtis JR, Teng GG, et al. Administrative codes combined with medical records based criteria accurately identified bacterial infections among rheumatoid arthritis patients. J Clin Epidemiol. 2009;62(3):321-7, 7 e1-7.
27. Stevenson KB, Khan Y, Dickman J, et al. Administrative coding data, compared with CDC/NHSN criteria, are poor indicators of health care-associated infections. Am J Infect Control. 2008;36(3):155-64.
28. 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):1433-41.
29. Platt R, Yokoe DS, Sands KE. Automated methods for surveillance of surgical site infections. Emerg Infect Dis. 2001;7(2):212-6.
30. Bolon MK, Hooper D, Stevenson KB, et al. Improved surveillance for surgical site infections after orthopedic implantation procedures: extending applications for automated data. Clin Infect Dis. 2009;48(9):1223-9.
31. Leal J, Laupland KB. Validity of electronic surveillance systems: a systematic review. J Hosp Infect. 2008;69(3):220-9.