Surgical Site Infections Occurring after Hospital Discharge

Kenneth Sands, Gordon Vineyard, and Richard Platt

Although surgical site infections (SSIs) occurring after hospital discharge cause substantial morbidity, their epidemiology is not well understood, and methods for routine postdischarge surveillance have not been validated. Inpatient and outpatient surveillance followed 5572 nonobstetric procedures among members of a health maintenance organization with extensive automated records. Records were screened for coded diagnoses, tests, and prescriptions and, if positive, were reviewed by reading full text. Questionnaires regarding the occurrence of an SSI were sent to the same patients and their surgeons. One hundred thirty-two SSIs were documented, of which 84% occurred after hospital discharge and 63% were managed outside the surgical facility. Postdischarge SSIs led to an average of 4.6 additional ambulatory encounters. Patient and surgeon questionnaires had a sensitivity of 28% and 15%, respectively. These data suggest that most SSIs occur after discharge and are not detectable by conventional surveillance. Nonetheless, they cause substantial resource utilization.

Postoperative surgical site infections (SSIs) are among the leading nosocomial causes of morbidity and increased medical expense. An estimated 325,000 SSIs occur each year in the United States and generate additional medical costs in the range of $1–2 billion [1, 2].

Routine surveillance for SSIs is recommended by both the Centers for Disease Control and Prevention (CDC) [3] and the Surgical Infection Society [4] as a mechanism for reducing the rate of these infections, presumably by providing feedback to surgeons on their performance [4–6]. SSI surveillance has been associated with decreased infection rates of as much as 35%, [3, 7] but even if the true effect of surveillance is much less than this, it would be highly cost-effective: the cost of surveillance has been estimated to be about one-fifth the cost of treating preventable infections [4, 8]. SSI rates are thus widely used by hospitals as a quality indicator and as the basis for quality improvement efforts.

Decreasing hospital lengths of stay and increasing use of ambulatory surgery may compromise the accuracy of surveillance data [9]. Traditionally, surveillance involved inpatient follow-up only, but previous studies have reported that as many as 71% of SSIs occur after hospital discharge [10–16]. For hospitals to report accurate absolute infection rates or to make comparisons of rates between hospitals, these infections must be identified [9, 16]. However, no reliable method for routine postdischarge wound surveillance has been established. Direct wound surveillance among outpatients is extremely resource-intensive, so many hospitals doing postdischarge surveillance now rely on responses to questionnaires mailed to either patients or surgeons [17]. To our knowledge, the performance characteristics of these questionnaires have never been rigorously evaluated. At the same time, there is little published information about resource utilization associated with postdischarge SSIs.

In this study, SSIs occurring before and after discharge were identified among members of a health maintenance organization for whom detailed information was available for all postdischarge medical encounters and prescriptions. For the same cohort, we evaluated the performance of mailed patient and surgeon questionnaires for detecting postdischarge SSIs and estimated the resource utilization associated with these infections.

Methods

Study population. The study population was drawn from adult members of Harvard Pilgrim Health Care (HPHC) who underwent a nonobstetric operating room procedure at Brigham and Women’s Hospital from 10 February 1992 through 7 March 1993. HPHC is a multimodel health maintenance organization that included a staff model division with ~300,000 members in the greater Boston area at the time of this study. Members pay a monthly fee, after which office visits, urgent care visits, and hospitalizations generate only nominal charges. At the time of the study, 92% of persons described above received care at centers that used an automated medical record system for both daily charting and archiving; only members with automated records were included in the study.

The automated medical record system uses standardized forms that are completed for every patient encounter at HPHC centers,
including telephone calls, office visits (scheduled or unscheduled),
urgent care visits, and hospitalizations. Information is recorded on
forms that are customized for the type of encounter. The provider
either writes in or selects from a list all coded diagnoses, tests,
procedures, and prescriptions relevant to that encounter and enters
additional comments as free text. All information, including free
text, is entered into an automated medical encounter record. The
results of diagnostic tests are entered directly into the automated
record linked to the patient encounter during which they were
ordered. Information about hospitalizations and emergency room
visits appear in both encounter records and separate administrative
records. HPHC pharmacies are also computerized and linked to
the automated medical record. Ninety percent of HPHC members
have prepaid coverage for pharmaceuticals and so are likely to use
HPHC pharmacies for any prescriptions that have more than a
nominal charge at outside pharmacies.

Brigham and Women’s Hospital is the most active surgical facil-
ity for greater Boston HPHC members. HPHC patients undergoing
surgery were identified within 3 weeks of their procedure from the
hospital’s computerized operating room log, which records
information on every operation in real time, including procedure
date, surgeons involved, duration of the procedure, wound class,
admission status of the patient, and up to three ICD-9 procedure
codes.

Identification of SSIs. Hospital-based information about SSIs
was identified by review of data gathered by the hospital’s infection
control unit, which uses routine microbiology, nurse’s notes, and
surgical ward rounds for surveillance, and review of the inpatient
charts of all patients receiving the ICD-9 code of 998.5 (postope-
tative wound infection) before discharge. Outpatient information
about SSIs was identified by a two-step procedure for reviewing
outpatient records that used the automated record systems de-
scribed above. The first step was a computerized search of three
automated data bases. Ambulatory encounter records were
screened for any of 102 diagnostic, testing, or treatment codes that
may have indicated an SSI. A partial list of these codes is given
in figure 1. The pharmacy data base was screened for specific
antibiotic prescriptions, and administrative records were searched
for all rehospitalizations or emergency room visits and their corre-
sponding ICD-9 codes for those potentially indicative of an SSI.
The second step was a physician review of full-text outpatient
records and relevant hospital records for the 30-day postoperative
period for all patients identified by the computerized search.

All records with any documentation suggestive of an SSI were
independently reviewed by 2 infectious disease physicians (K.S.
and R.P.). Final classification as an SSI required agreement that
documentation meeting the 1992 CDC definition of SSI [18] was
present within 30 days of the procedure. For cases in which there
was disagreement, a third independent review was done by a sur-
geon (G.V.), and the majority opinion was accepted. Because pri-
mary outpatient care was often provided by a physician’s assistant,
a diagnosis of SSI made by this provider was considered equivalent
to physician’s diagnosis; a physician would have had to review
the diagnosis and findings in these cases if they involved prescrip-
tion of an antibiotic.

Assessment of resource utilization. Resource utilization asso-
ciated with postdischarge SSI during the 30-day postoperative pe-
riod was explored by review of outpatient records for patients
with a confirmed postdischarge infection. All free-text notes were
reviewed, and encounters for which the principal focus was the
SSI were identified. Other activities associated with the SSI, such
as home care visits, prescriptions, and laboratory tests, were also
identified if there was clear indication that these activities related
directly to the infection.

Patient and surgeon questionnaires. Patients were mailed a
single-page questionnaire between the 25th and 32nd postoperative
day. A questionnaire was not sent if the patient had died or was
an inpatient (either not discharged or discharged and readmitted)
at the surgical facility during the time window for mailing the
questionnaire. The patient questionnaire appeared in both English
and Spanish and was preaddressed and stamped for return. The
questionnaire provided yes-no checkboxes for questions falling
within three categories: whether the patient had been treated for
any problems during the postoperative period, with “infection at
your surgical incision” as one of the listed choices; whether the
patient had made any urgent or unplanned visits to any health care
facility since the operation; and whether any new medications had
been prescribed since leaving the hospital, with antibiotic listed
as one of the choices. While open-ended comments were solicited,
the questionnaire did not focus on the patient’s subjective assess-
ment of the wound, which has been shown to correlate poorly with
physician findings [19].

Surgeons were mailed a form every 4 weeks that listed their
surgical cases among the study population from 4–8 weeks earlier.
The form displayed patient name, date of the procedure, and type
of procedure. Adjacent to the patient name, the surgeon was asked
to indicate whether an SSI occurred, with the possible responses
being “definite,” “possible,” “no,” or “don’t know.” The form
was sent with a cover letter explaining that responses would not
be used to assess individual surgeon performance and listing the
CDC definition of SSI in abbreviated form. Surgeons were not
notified of the concurrent chart review and patient questionnaire.

Analysis. Surgical procedures were categorized according to
the National Nosocomial Infections Surveillance System (NNIS),
which classifies all ICD-9 surgical codes into 44 operative catego-
ries (42 of which are nonobstetric), primarily on the basis of ana-
atomic location of the surgery [20]. Procedures that do not qualify
as operative procedures (for example, needle biopsy, transurethral
prostatectomy) by the NNIS were included in the analysis as a
separate nonoperative category. The NNIS categories were then
collapsed into 10 new categories based on surgical specialty. SSI
rates were calculated for each of the NNIS nonobstetric operative
categories and for each of the 10 larger procedure categories.
Attack rates were calculated for predischarge, postdischarge, and
total events.

Positive questionnaire responses for procedures not identified
as associated with an SSI were investigated by chart review to
determine whether these were false-positive responses or true SSIs
that had been missed by our case-finding methodology.

Performance characteristics of patient and surgeon question-
naires were compared with the record review procedure by calcula-
tion of sensitivity, specificity, and positive predictive value for a
positive questionnaire response. Calculations were made both for
procedures for which a questionnaire was returned and for the
entire population, in which case an unreturned questionnaire was
considered negative. In addition, for surgeon questionnaires, per-
formance was evaluated by interpreting “possible SSI” first as a
positive response and then as a negative response.
The performance of each separate component of our automated screening strategy was also evaluated and compared with aggregate performance and with the results of hospital-based surveillance. We considered inpatient ICD-9 discharge diagnosis codes; emergency room ICD-9 diagnosis codes; ambulatory care diagnosis, test, and treatment codes as a group; obtaining wound or blood cultures in the ambulatory setting; and dispensing of the 10 principal oral antibiotic agents used to treat SSIs at HPHC.

**Results**

**Record review.** The study population consisted of 5042 HPHC members who underwent 5572 nonobstetric operative procedures. All nonobstetric NNIS categories were represented, plus 1465 procedures classified as nonoperative. Table 1 presents summary information about the patient population and procedure types.

Review of inpatient records with an SSI indicated by prospective inpatient surveillance or with discharge coding indicating an SSI identified 27 events, all of which were confirmed to meet CDC criteria for SSI. Screening of automated ambulatory encounter, pharmacy, and administrative records identified 741 procedures. Review of the relevant full-text records for this group identified 105 additional SSIs. Agreement between the two infectious disease physicians regarding the presence or absence of infection exceeded 95%. The overall attack rate for SSI was 2.4%; it was 0.7% for predischarge events (among inpatients) and 2.0% for postdischarge events. Of the total 132 SSIs identified, 111 (84%) occurred after discharge, and 70 (63%) of these were diagnosed and treated entirely outside of the institution at which the surgery was done. The median postoperative length of stay for inpatients with a postdischarge SSI was 4 days; all occurred among patients with a postoperative length of stay of ≤14 days.

There were 53 positive patient responses and 44 positive surgeon responses relating to procedures not identified as complicated by an SSI by our methodology. Review of inpatient and outpatient records for these patients identified 1 postoperative event meeting criteria for an SSI. This event qualified as an SSI on the basis of a physician’s diagnosis (in free text only, on a single visit) after noting wound erythema, which was not treated with antibiotics. The majority of false-positive responses from patients represented minor wound complications that were documented in the ambulatory record but did not meet NNIS criteria for SSI. The majority of false-positive responses from surgeons related to procedures done on sites that were infected preoperatively.

Figure 2 shows pre- and postdischarge SSI attack rates within 10 procedure categories, derived from collapsing the more specific NNIS classification scheme. Attack rates ranged from 0 (0/204) for neurosurgical procedures to 10.3% (27/261) for cardiothoracic procedures. Pre- and postdischarge SSI attack rates within these 10 categories and each of the 42 NNIS nonobstetric procedure categories are summarized in table 2.

**Resource utilization.** During the 30-day postoperative period, the 111 procedures complicated by a postdischarge SSI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ambulatory (n = 2479)</th>
<th>Inpatient (n = 3093)</th>
<th>Total (n = 5572)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient age in years, median</td>
<td>41</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>Procedure length in minutes, median</td>
<td>35</td>
<td>105</td>
<td>65</td>
</tr>
<tr>
<td>% female</td>
<td>65</td>
<td>60.5</td>
<td>63</td>
</tr>
<tr>
<td>Postoperative length of stay in days, median (range)</td>
<td>NA</td>
<td>4 (0-121)</td>
<td>NA</td>
</tr>
<tr>
<td>Wound classification (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean</td>
<td>71.0</td>
<td>62.1</td>
<td>66.1</td>
</tr>
<tr>
<td>Clean-contaminated</td>
<td>25.0</td>
<td>29.2</td>
<td>27.5</td>
</tr>
<tr>
<td>Contaminated</td>
<td>3.1</td>
<td>5.5</td>
<td>4.4</td>
</tr>
<tr>
<td>Dirty</td>
<td>0.5</td>
<td>3.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

NOTE. NA, not applicable.
necessitated 37 emergency room visits, 37 hospitalizations, 202 scheduled clinical appointments at HPHC (mean, 1.8; range, 0–8), 117 home care visits (mean, 1.1; range, 0–20), and 155 nonappointment encounters (mean, 1.4; range, 0–6), such as telephone calls or visits for laboratory tests, that could be verified as directly attributable to the infection. The average number of additional ambulatory or emergency room encounters was 4.6 (511/111). The 70 procedures that necessitated no SSI-related rehospitalizations or emergency room visits accounted for 147 scheduled clinical appointments, 41 home visits, and 48 nonappointment encounters verified as attributable to their infection. In other words, 50% (236/474) of SSI-related outpatient encounters occurred among patients diagnosed and treated without a revisit to the institution where surgery was done. These figures are likely to be underestimates, since no attempt was made to include services that were partly attributable to the infection or services that occurred after the 30th postoperative day.

Questionnaire information. Questionnaires were mailed to patients regarding 5388 procedures. They were not sent to 184 patients who either had died or were inpatients at the surgical facility at the time of the mailing; these 184 included 6 with SSIs, 2 of whom had never been discharged and 4 who had been readmitted for treatment of their infection. All 5572 procedures were represented on the monthly forms sent to surgeons. Patient questionnaires were returned for 1799 procedures (33.4%) and surgeon questionnaires for 4420 procedures (79%).

Table 3 shows the results of patient and surgeon responses in relation to the actual occurrence of SSI, excluding the 21 predischarge SSIs. The sensitivity of a positive patient response was 28% and the positive predictive value was 36%. The sensitivity of a positive patient response rose to 68% if the unreturned questionnaires were excluded. For surgeon questionnaires, if a response of possible SSI was interpreted as negative, the sensitivity was 15% and the positive predictive value was 28%. If possible SSI was considered a positive response, these figures were 24% and 19%, respectively.

Performance characteristics of selected automated screening criteria. The performance characteristics of separate components of our automated screening are shown in figure 3, along with the performance of patient and surgeon questionnaires. Coded diagnoses, tests, and treatments in the ambulatory medical record identified 84% of infections (93/111), with a positive predictive value of 17% (93/533). Dispensing of an antibiotic commonly used to treat soft tissue infections was next best, with a sensitivity of 50% (56/111) and a positive predictive value of 19% (56/289). No other single component had a sensitivity >40%. A hospital-based surveillance program that reviewed all emergency room visits and hospital readmissions would have had a sensitivity of 39% (43/111) and a
### Table 2. Predischarge and postdischarge SSI rates within specific National Nosocomial Infection Surveillance (NNIS) procedure categories.

<table>
<thead>
<tr>
<th>Operative category</th>
<th>NNIS code</th>
<th>No. of predischarge SSIs</th>
<th>% of total</th>
<th>No. of predischarge SSIs</th>
<th>% of total</th>
<th>No. of postdischarge SSIs</th>
<th>% of total</th>
<th>% of SSIs occurring after discharge</th>
<th>% of SSIs</th>
<th>% of postdischarge SSIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary bypass/leg incision</td>
<td>cbgb</td>
<td>96 (1.7)</td>
<td>7</td>
<td>7.3</td>
<td>13</td>
<td>13.5</td>
<td>65</td>
<td>11.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary bypass/single incision</td>
<td>cbgc</td>
<td>6 (0.1)</td>
<td>1</td>
<td>16.7</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac valve and septum</td>
<td>card</td>
<td>31 (0.6)</td>
<td>1</td>
<td>3.2</td>
<td>2</td>
<td>6.5</td>
<td>66.7</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic surgery</td>
<td>thor</td>
<td>83 (1.5)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other cardiovascular</td>
<td>ocv</td>
<td>45 (0.8)</td>
<td>0</td>
<td>0.0</td>
<td>3</td>
<td>6.7</td>
<td>100</td>
<td>2.7</td>
<td></td>
<td></td>
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<tr>
<td>All cardiothoracic</td>
<td></td>
<td>261 (4.7)</td>
<td>9</td>
<td>3.4</td>
<td>18</td>
<td>6.9</td>
<td>67</td>
<td>16.2</td>
<td></td>
<td></td>
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<tr>
<td>Vascular</td>
<td>vs</td>
<td>91 (1.6)</td>
<td>1</td>
<td>1.1</td>
<td>4</td>
<td>4.4</td>
<td>80</td>
<td>3.6</td>
<td></td>
<td></td>
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<tr>
<td>Nephrectomy</td>
<td>neph</td>
<td>27 (0.5)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<tr>
<td>Organ transplant</td>
<td>tp</td>
<td>5 (0.1)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>20.0</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
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<tr>
<td>Prostatectomy*</td>
<td>prst</td>
<td>23 (0.4)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>4.3</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
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<tr>
<td>Other genitourinary system</td>
<td>ogu</td>
<td>293 (5.3)</td>
<td>3</td>
<td>1.0</td>
<td>9</td>
<td>3.1</td>
<td>75</td>
<td>8.1</td>
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<td></td>
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<tr>
<td>All urology</td>
<td>uro</td>
<td>348 (6.2)</td>
<td>3</td>
<td>0.9</td>
<td>11</td>
<td>3.2</td>
<td>58</td>
<td>9.9</td>
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<tr>
<td>Skin graft</td>
<td>skgr</td>
<td>19 (0.3)</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>10.5</td>
<td>100</td>
<td>1.8</td>
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<tr>
<td>Other integumentary system</td>
<td>oskn</td>
<td>499 (9.0)</td>
<td>0</td>
<td>0.0</td>
<td>13</td>
<td>2.6</td>
<td>100</td>
<td>11.7</td>
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<tr>
<td>All plastic surgery</td>
<td>plas</td>
<td>518 (9.3)</td>
<td>0</td>
<td>0.0</td>
<td>15</td>
<td>2.9</td>
<td>100</td>
<td>13.5</td>
<td></td>
<td></td>
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<tr>
<td>Abdominal hysterectomy</td>
<td>hyst</td>
<td>151 (2.7)</td>
<td>1</td>
<td>0.7</td>
<td>3</td>
<td>2.0</td>
<td>75</td>
<td>2.7</td>
<td></td>
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<tr>
<td>Vaginal hysterectomy</td>
<td>vhys</td>
<td>55 (1.0)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>1.8</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
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<tr>
<td>All gynecologic</td>
<td>gyn</td>
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<td>1</td>
<td>0.5</td>
<td>4</td>
<td>1.9</td>
<td>80</td>
<td>3.6</td>
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<td>mast</td>
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<td>0.0</td>
<td>12</td>
<td>2.5</td>
<td>100</td>
<td>10.8</td>
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<tr>
<td>Splenectomy</td>
<td>sple</td>
<td>18 (0.3)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>5.6</td>
<td>100</td>
<td>0.9</td>
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<tr>
<td>Appendectomy</td>
<td>appy</td>
<td>132 (2.4)</td>
<td>1</td>
<td>0.8</td>
<td>2</td>
<td>1.5</td>
<td>67</td>
<td>1.8</td>
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<tr>
<td>Bile duct/liver/pancreatic</td>
<td>bili</td>
<td>10 (0.2)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>10.0</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholecystectomy</td>
<td>chol</td>
<td>292 (5.2)</td>
<td>0</td>
<td>0.0</td>
<td>7</td>
<td>2.4</td>
<td>100</td>
<td>6.3</td>
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</tr>
<tr>
<td>Gastric surgery</td>
<td>gast</td>
<td>23 (0.4)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
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<tr>
<td>Small bowel surgery</td>
<td>sb</td>
<td>24 (0.4)</td>
<td>1</td>
<td>4.2</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
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<tr>
<td>Colon surgery</td>
<td>colo</td>
<td>83 (1.5)</td>
<td>3</td>
<td>3.6</td>
<td>1</td>
<td>1.2</td>
<td>25</td>
<td>0.9</td>
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<tr>
<td>Herniorrhaphy</td>
<td>her</td>
<td>279 (5.0)</td>
<td>0</td>
<td>0.0</td>
<td>3</td>
<td>1.1</td>
<td>100</td>
<td>2.7</td>
<td></td>
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<tr>
<td>Laparotomy</td>
<td>xlap</td>
<td>72 (1.3)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>1.4</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other digestive system</td>
<td>ogit</td>
<td>101 (1.8)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>1.0</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All general surgery</td>
<td>gen</td>
<td>1505 (27)</td>
<td>5</td>
<td>0.3</td>
<td>29</td>
<td>1.9</td>
<td>85</td>
<td>26.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open reduction fracture</td>
<td>fx</td>
<td>124 (2.2)</td>
<td>1</td>
<td>0.8</td>
<td>2</td>
<td>1.6</td>
<td>67</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limb amputation</td>
<td>amp</td>
<td>23 (0.4)</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>4.3</td>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip prosthesis</td>
<td>hpro</td>
<td>58 (1.0)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<td>Knee prosthesis</td>
<td>kpro</td>
<td>38 (0.7)</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>5.3</td>
<td>100</td>
<td>1.8</td>
<td></td>
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<tr>
<td>Other joint prosthesis</td>
<td>opro</td>
<td>43 (0.8)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
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<td></td>
</tr>
<tr>
<td>Spinal fusion</td>
<td>fusn</td>
<td>9 (0.2)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other musculoskeletal</td>
<td>oms</td>
<td>537 (9.6)</td>
<td>0</td>
<td>0.0</td>
<td>11</td>
<td>2.0</td>
<td>100</td>
<td>9.9</td>
<td></td>
<td></td>
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<tr>
<td>All orthopedic</td>
<td>orth</td>
<td>832 (14.9)</td>
<td>1</td>
<td>0.1</td>
<td>16</td>
<td>1.9</td>
<td>94</td>
<td>14.4</td>
<td></td>
<td></td>
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<tr>
<td>Cranietomy</td>
<td>crani</td>
<td>54 (1.0)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laminectomy</td>
<td>lam</td>
<td>58 (1.0)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<td>Ventricular shunt</td>
<td>vshn</td>
<td>5 (0.1)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<tr>
<td>Other neurosurgical</td>
<td>ons</td>
<td>87 (1.6)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All neurosurgery</td>
<td>ns</td>
<td>204 (3.7)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck surgery</td>
<td>hn</td>
<td>7 (0.1)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other otolaryngology</td>
<td>oent</td>
<td>50 (0.9)</td>
<td>1</td>
<td>2.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<tr>
<td>Other hemic/lymphatic</td>
<td>obl</td>
<td>20 (0.4)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other endocrine system</td>
<td>oes</td>
<td>49 (0.9)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other eye</td>
<td>oeye</td>
<td>7 (0.1)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other respiratory system</td>
<td>ores</td>
<td>9 (0.2)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other</td>
<td>all</td>
<td>142 (2.5)</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
<td></td>
<td></td>
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<tr>
<td>Nonoperative</td>
<td>non</td>
<td>1465 (26.3)</td>
<td>0</td>
<td>0.0</td>
<td>14</td>
<td>1.0</td>
<td>100</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5572 (100)</td>
<td>21</td>
<td>0.4</td>
<td>111</td>
<td>2.0</td>
<td>84</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. NA, not applicable. *Excludes transurethral resection of prostate.
Table 3. Performance of patient and surgeon questionnaires for the detection of surgical wound infection.

<table>
<thead>
<tr>
<th>Record review</th>
<th>Patient response</th>
<th>Surgeon response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SSI</td>
<td>No SSI</td>
</tr>
<tr>
<td>Postdischarge SSI ( (n = 111) )</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>No SSI ( (n = 5440) )</td>
<td>53</td>
<td>1699</td>
</tr>
</tbody>
</table>

Positive predictive value of 7% \( (43/622) \); a program that reviewed ICD-9-specific emergency room visits and hospital readmissions would have had a sensitivity of 30% \( (33/111) \) and a positive predictive value of 41% \( (33/81) \).

**Discussion**

The pairing of screening of automated records and review of selected full-text records was both sensitive and efficient for identifying SSI because we retrieved information about outpatient care through automated clinical, laboratory, pharmacy, and administrative databases; we could review all full-text records of persons who met screening criteria; and patient and surgeon questionnaires identified a negligible number of additional infections.

The percentage of SSIs occurring after hospital discharge was high (84%), reflecting in part the inclusion of procedures done in the ambulatory setting or with a very short stay in the hospital. However, even for major surgical procedures (e.g., cardiac surgery), the majority of SSIs occurred after discharge.

**Figure 3.** Strategies for screening for postdischarge SSIs. Plot shows sensitivity (x-axis) and positive predictive value (y-axis) of seven candidate methodologies. Numbers in parentheses show number of true-positive, false-positive, and false-negative responses, respectively, for given methodology. All points are based on 111 postdischarge SSIs occurring among 5551 procedures (21 procedures leading to predischarge SSIs were excluded) except “patient questionnaire.” Because patient questionnaires were not sent if person was known to be deceased or in hospital at time of mailing, this point is based on 107 SSIs occurring among 5388 procedures.
Furthermore, the majority (63%) of the 84% of SSIs that occurred after hospital discharge were diagnosed and treated entirely in the ambulatory setting. In this cohort, if the institution had identified every predischarge SSI and every postdischarge SSI leading to a rehospitalization or emergency room visit, the recognized SSI attack rate would have been 1.1% (62/5572), while the actual attack rate was 2.4% (132/5572).

These postdischarge SSIs were associated with important resource utilization. There were on average 4.6 outpatient encounters attributable to the SSI and a substantial number of emergency room visits and rehospitalizations. There were a significant number of additional outpatient visits even among the 70 postdischarge SSIs that did not lead to an emergency room visit or rehospitalization: 236 encounters, or an average of 3.4 encounters/SSI for this group. This is a minimal estimate of resource utilization, as only those events occurring within 30 postoperative days and verified as primarily relating to the SSI were included. More accurate assessment of the resource utilization associated with these infections will require assessment of total utilization for those with and without infection, while controlling for important potential sources of bias.

The patient and surgeon questionnaires used in this study proved to have both low sensitivity and positive predictive value for detection of true SSIs. Patient questionnaires were insensitive largely because of the return rate of only 33.4%, a proportion similar to previous studies using a single mailed questionnaire [21]. On the other hand, surgeon questionnaires had a high return rate but were even less sensitive than patient questionnaires because many responses were falsely negative. Potential reasons for the poor sensitivity of surgeon questionnaires include lack of awareness of postdischarge infections (because postoperative follow-up was delivered by a different provider) or failure to remember such infections by the time they received the form.

The reasons for poor predictive value also differed between patient and surgeon responses. For patients, false-positive responses typically represented minor wound complications not meeting criteria for SSI. For surgeons, the majority of false-positive responses related to reporting of preoperatively infected sites, despite the fact that questionnaires included a cover letter explaining that only postoperative events should be reported.

The poor performance of patient and surgeon questionnaires (as a one-time mailing) highlights the need for further investigation of methods of postdischarge surgical site surveillance. The usefulness of patient questionnaires might be improved by strategies to improve the return rate, such as multiple mailings, telephone contacts, or discussing the questionnaire before discharge. For surgeons, other strategies would be necessary, since their response rate was satisfactory. The impact of these maneuvers is not known, but questionnaire performance would have to be dramatically better than the current findings to be a useful and efficient method for routine surveillance.

The current study used a case-finding method designed for maximal sensitivity at the expense of requiring full-text review of >10% of records. Future studies should focus on the methodology or combination of methodologies that provides the best combination of sensitivity and efficiency. We found that review of automated data bases was extremely useful as a screening methodology for SSIs. While there are currently few institutions with access to entirely automated records, these are likely to become increasingly available. An efficient mechanism for capturing emergency room visits and rehospitalizations, ideally in association with coded diagnoses, would allow a hospital to capture 39% of postdischarge SSIs. Screening outpatient antibiotic prescriptions may also be worthwhile. It should also be noted that postdischarge SSI rates varied dramatically among NNIS procedure categories. More than 75% of postdischarge SSIs fell within 17 NNIS categories, representing <50% of procedures. An efficient surveillance program may choose to focus surveillance on certain procedure groups, perhaps tailored to the case mix at that institution. Limiting surveillance to those with a postoperative length of stay of <14 days (the longest postoperative length of stay for which a postdischarge SSI was detected) would not have been an effective method since it would have eliminated the need for surveillance for only 5% of our population. Except for the few procedures with a postoperative length of stay of >14 days, the distribution of postoperative length of stay was very similar for procedures with and without an associated postdischarge SSI, including an identical median of 4 days.

Our overall SSI attack rate is lower than most previously published attack rates for SSIs [3, 5, 10, 12–14, 22–26]. There may be several reasons for this. First, the population included many low-risk procedures (clean, low anesthesia risk scores, brief duration). Many were ambulatory procedures that have not been carefully studied before this (including >25% categorized as nonoperative by the NNIS classification scheme). Second, our protocol required written documentation of findings meeting the CDC definition of SSI. Events occurring after 30 days were not included and, unlike some studies [26], antibiotic treatment alone for a wound complication did not meet diagnostic criteria. Nonetheless, there was substantial infection-related morbidity and resource utilization. Finally, it is possible that our surveillance failed to detect a significant number of SSIs. We think this unlikely for reasons stated above, but in lieu of a true reference standard, estimates of the number of infections should be understood to be lower bounds and sensitivity measures as upper bounds.

We conclude that the majority of SSIs occur after hospital discharge and that these infections are associated with important morbidity and resource utilization. Identification of SSIs will require that hospitals, managed care organizations, and insurers perform some form of postdischarge surveillance. This investigation has demonstrated the considerable disadvantages of mailed questionnaires, which are both less accurate (lower sensitivity and lower specificity) and more resource-intensive than use of automated administrative and patient care data, which are becoming increasingly available. Additional
effort is warranted to identify optimally efficient screening and confirmation methods and to better define the risk factors for postdischarge SSIs that might allow for a surveillance strategy that focuses on high-risk groups.

Acknowledgments

We thank Emily Cain, Michelle Cordeiro, Jeffrey Hansen, and James Livingston for their assistance in this study.

References