Published in final edited form as:

Ann Surg. 2010 December ; 252(6): 1065–1071. doi:10.1097/SLA.0b013e3181dcf36e.

Postoperative sepsis in the United States

Todd R. Vogel, MD MPH, Viktor Y. Dombrovskiy, MD PhD MPH, Jeffrey L. Carson, MD^{*}, Alan M. Graham, MD, and Stephen F. Lowry, MD

Robert Wood Johnson Medical School, Department of Surgery, The Surgical Outcomes Research Group, New Brunswick, New Jersey.

^{*}Division of General Internal Medicine, New Brunswick, New Jersey.

Abstract

Objectives—To evaluate the incidence of postoperative sepsis after elective procedures, to define surgical procedures with the greatest risk for developing sepsis, and to evaluate patient and hospital confounders

Background Data—The development of sepsis after elective surgical procedures imposes a significant clinical and resource utilization burden in the United States. We evaluated the development of sepsis after elective procedures in a nationally-representative patient cohort and assessed the impact of sociodemographic and hospital characteristics on the development of postoperative sepsis.

Methods—The Nationwide Inpatient Sample was queried between 2002-2006 and patients developing sepsis after elective procedures were identified utilizing the Patient Safety Indicator “Postoperative Sepsis” (PSI-13). Case mix–adjusted rates were calculated by using a multivariate logistic regression model for sepsis risk and an indirect standardization method.

Results—6,512,921 weighted elective surgical cases met the inclusion criteria and 78,669 cases (1.21%) developed postoperative sepsis. Case-mix adjustment for age, race, gender, hospital bed size, hospital location, hospital teaching status, and patient income demonstrated esophageal, pancreatic, and gastric procedures represented the greatest risk for the development of postoperative sepsis. Thoracic, adrenal, and hepatic operations accounted for the greatest mortality rates if sepsis developed. Increasing age, Blacks, Hispanics, and men were more likely to develop sepsis. Decreased median household income, larger hospital bed size, urban hospital location, and non-teaching status were associated with greater rates of postoperative sepsis.

Conclusions—The development of postoperative sepsis is multifactorial and procedures most likely to develop sepsis did not demonstrate the greatest mortality after sepsis developed. Factors associated with the development of sepsis included race, age, hospital size, hospital location, and patient income. Further evaluation of high risk procedures, populations, and environments may assist in reducing this costly complication.

Corresponding Author: Todd R. Vogel, MD, MPH, University of Medicine and Dentistry of New Jersey, Robert Wood Johnson Medical School, Division of Vascular Surgery, One Robert Wood Johnson Place - MEB-541, New Brunswick, New Jersey 08903-0019 .

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Introduction

The development of sepsis creates a substantial health care burden and limited epidemiologic information exists with regard to postoperative sepsis. Martin et al. demonstrated that the incidence of sepsis and the number of sepsis-related deaths are increasing, although the overall mortality rate among patients with sepsis is declining.¹ The National Healthcare Quality Reports estimated 11.6 cases of post-operative sepsis per 1,000 elective surgery discharges with hospital length of stay longer than 3 days.² Other population studies focusing on elective procedures have demonstrated that the rates of sepsis and severe sepsis have increased significantly over the last decade with little improvement in overall mortality.³ Sepsis remains one of the leading causes of death in the United States and surgical patients account for approximately one third of all sepsis cases.⁴

As payers move toward performance-based reimbursement, evaluation of hospital performance will become more important⁵ and studies focusing on higher risk surgical procedures and best practices to prevent possible complications may offer future targets for intervention. Administrative data offers the ability to evaluate large numbers of interventions, to delineate procedures more prone to complications, and to describe hospital and patient characteristics associated with septic complications after elective surgery.

The objective of this study was to describe the epidemiology of post-operative sepsis in the United States after elective in-patient elective surgery by procedure type. Secondary aims included description of sociodemographic factors and hospital characteristics associated with the development of postoperative sepsis. The identification of high risk groups may assist in identifying process level opportunities for improvements to reduce the incidence of sepsis.

Methods

Data Source

The Nationwide Inpatient Sample (NIS) was queried for the years 2002-2006. This database was developed as part of the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality (AHRQ).⁶ Being the largest all-payer hospital database in the United States it contains information about all hospitalizations from more than 1,000 acute care hospitals representing a 20% weighted probability sample of all US hospitals. Sampling strata created by AHRQ are based on hospital characteristics including geographic region, ownership, location, teaching status, and number of beds and sampling weights are provided to account for the survey design and to provide national estimates. The most current NIS data includes approximately 8 million hospitals admissions annually and, utilizing the weighting function methodology provided by HCUP, allows for the computation of national estimates with variances for specific variables. All data were analyzed and results were reported utilizing the weighting methodology included with the NIS⁷⁻⁸ and as previously reported in other epidemiologic outcomes studies in surgery.⁹

Study Population

To identify the study population, we followed the selection criteria in the technical specifications developed by the AHRQ for the Patient Safety Indicator "Postoperative Sepsis" (PSI-13)¹⁰, and used specific DRG (Diagnosis-Related Groups) and ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes provided by this document. The AHRQ and the Stanford-UCSF Evidence-based Practice Center have developed Patient Safety Indicators (PSIs). PSIs were developed after a comprehensive literature review, analysis of ICD-9-CM codes, review by a clinician panel, implementation of risk adjustment, and empirical analyses. Among 20 hospital-level

indicators, eight are related to surgical discharges and may be utilized to identify potential adverse events. The indicator, post-operative sepsis (PSI 13), was utilized to identify sepsis as a complication. Patient Safety Indicators are particularly applicable to surgical patients as they are more homogeneous than medical patients making it easier to account for case-mix.

Observations with post-operative sepsis had the following ICD-9-CM diagnosis codes in any secondary position (suggesting a complication from the surgical procedure) for the diagnosis codes: Streptococcal septicemia (038.0), Staphylococcal septicemia unspecified (038.10), Staphylococcus aureus septicemia (038.11), Other Staphylococcal septicemia (038.19), Pneumococcal septicemia (038.2), Septicemia due to anaerobes (038.3), Gram-negative organism unspecified (038.40), Hemophilus influenzae (038.41), Escherichia coli (038.42), Pseudomonas (038.43), Serratia (038.44), Septicemia due to other Gram-negative organisms (038.49), Other specified septicemias (038.8), Unspecified septicemia (038.9), Septic Shock (785.52), Other shock without mention of trauma (785.59), Systemic inflammatory response syndrome due to infectious process without organ dysfunction (995.91), Systemic inflammatory response syndrome due to infectious process with organ dysfunction (995.92).¹¹

However, procedures associated with cancer were not excluded due to the importance of this diagnosis as an indication for some major surgical procedures. As a result, we included in the study cohort surgical patients age 18 years and older who were electively admitted to the hospital, did not have diagnosis of sepsis, any infection or any reported immunocompromised status at admission, and stayed in the hospital no less than 4 days.

Using the ICD-9-CM and CCS (Clinical Classification Software) procedure codes for principal procedures in the data, we also selected 15 major specific groups of surgical procedures (Table 1). When selecting study population for this analysis, we found the interval between the day of admission to the hospital and a day when procedure of interest was performed varied considerably. To ensure that patients were hospitalized for surgical procedure of interest, we selected only those cases where the procedure was the principal procedure and performed within two days of admission. Our preliminary analysis demonstrated that 90 percent of procedures were performed during the first two days after admission and we restricted our cohort to these patients. This approach has been previously utilized in administrative data to ensure elective procedures are evaluated.¹²

Statistical Analysis

SAS 9.2 software (SAS Institute, Cary, NC) was used for the analysis of data and all statistics. We tested the difference between two groups with χ^2 analysis for categorical variables and with *t*-test for continuous variables. Because hospital length of stay and cost are highly skewed, medians were calculated for these parameters and intergroup differences were evaluated with the non-parametric Wilcoxon rank-sum test. Trends in the parameter estimates were analyzed with the Cochran-Armitage trend test. A value of $P < 0.05$ was considered significant for all calculations.

Patient and hospital characteristics were adjusted utilizing logistic regression models that included these characteristics as independent variables. Elixhauser comorbidity measures were utilized to identify and adjust for comorbidities in the cohort and to perform case-mix adjustment.¹³⁻¹⁵ The NIS data includes 30 AHRQ comorbidity measures reported by Elixhauser et al.¹⁴ To identify these comorbidities we used the Comorbidity Software developed as part of the Healthcare Cost and Utilization Project (HCUP). Hospital bed size categories in the NIS (small, medium, and large) are based on the number of hospital beds with regards to the hospital location and teaching status as defined by HCUP.¹⁶

Case Mix Adjustment

Crude rates of postoperative sepsis were calculated by dividing the number of observations with infection by the number of all observations and expressed as a percentage. Crude rates for mortality were calculated by dividing the number of fatal cases by the total number of cases in each group and also expressed as a percentage. Risk-adjusted rates of sepsis and mortality for each group of surgical procedures were calculated utilizing indirect standardization. To perform case-mix adjustment, the expected rates for each procedure were calculated using a logistic regression model created with sepsis or death as the dependent variable (outcome) and the independent variables were identified as predictors of this outcome. Predictors included in the model were age, gender, and race, AHRQ comorbidities, hospital bed size, hospital location, and hospital teaching status. This methodology allows for the adjustment of the observed rates of sepsis by these defined factors. Variable interactions were evaluated using SAS PROC MIXED statement and no significant interactions were noted. The mean predicted probability of outcome was then calculated for each procedure and the expected rate as a percentage was generated. Following these calculations we divided observed rate for each procedure by the expected rate for this procedure and multiplied by the observed rate for the entire sample. This methodology has been previously reported in epidemiological studies to calculate case-mix adjusted rates.¹⁷⁻¹⁹

Cost Analysis

Hospital cost was calculated using total hospital charge in the database and the HCUP Cost-to-Charge ratio files. Total hospital charges in various years were adjusted to charges in 2006 with the CPI inflation calculator provided by the US Department of Labor.²⁰ Total hospital cost in various groups was presented as median and comparisons were made with the non-parametric Wilcoxon rank-sum test. For analysis by income, the NIS database contains a categorization of the estimated median household income of residents in the patient's ZIP code by quartile, from 1st quartile with the lowest income to 4th quartile with the highest income.

Results

An estimate of 6,512,921 elective surgical cases met the eligibility criteria. The sociodemographic characteristics of the whole study cohort are displayed in Table 2. The majority of the patients (51.4%) were 65 years and above, female ($P < 0.0002$), and white (82.1%). More than half of all patients were insured by Medicare (51.7%) and 37.9% were privately insured.

Overall Incidence and Sociodemographics

Overall, 1.21% ($N = 78,669$) patients developed postoperative sepsis. The rate of sepsis steadily increased with the increasing age ($P < 0.001$ for trend) and octogenarians were almost twice as likely to develop sepsis as persons aged less than 50 years (OR [odds ratio] = 1.97; 95% CI 1.92, 2.03). The greatest rates of postoperative sepsis were found in Blacks who were more likely to develop postoperative sepsis compared to whites (OR = 1.28; 95% CI 1.25, 1.32). Hispanics were also more likely to develop postoperative sepsis compared to whites (OR = 1.20; 95% CI 1.16, 1.24).

Analyzing rates of postoperative sepsis by insurance status, we found that patients with Medicare and Medicaid were significantly more likely to develop sepsis than patients with private insurance coverage (OR = 1.78; 95% CI 1.75, 1.81 and OR = 1.75; 95% CI 1.69, 1.80, respectively). Uninsured patients were 1.21 times (95% CI 1.14, 1.28) as likely to have postoperative sepsis as patients with private insurance. We also evaluated rates of

postoperative sepsis in patients with varying incomes. The NIS database stratifies the estimated median household income of residents in the patient's ZIP code by quartile, from 1st quartile with the lowest income to the 4th quartile with the greatest income. The rate of sepsis was higher in patients with lower income ($P < 0.0001$ for trend). A steady decrease in sepsis was found by income quartile: 1st 1.44%; 2nd 1.25% ($P < 0.0001$); 3rd 1.18%; ($P < 0.0001$); and 4th (1.15%; $P = 0.0143$) quartiles.

Rates of postoperative sepsis were also associated with various hospital characteristics. Patients in large size hospitals were more likely to develop sepsis after elective surgical procedures than patients in small size hospitals (OR = 1.05; 95% CI 1.02, 1.09). Also, elective surgical procedures performed in urban and non-teaching hospitals were more likely to be complicated by postoperative sepsis compared to rural (OR = 1.32; 95% CI 1.27, 1.37) and teaching (OR = 1.056; 95% CI 1.042, 1.071) hospitals.

Multivariate logistic regression analysis was utilized to determine factors associated with postoperative sepsis. Significant sepsis predictors included octogenarians compared to patients 50 years and younger (OR = 2.05; 95% CI 1.97, 2.13) and blacks and Hispanics compared to whites (OR = 1.36; 95% CI 1.31, 1.41 and OR = 1.33; 95% CI 1.27, 1.39, respectively). Risk factors associated with a lower risk of sepsis were female gender (OR = 0.71; 95% CI 0.69, 0.72), teaching status of the hospital (OR = 0.90; 95% CI 0.88, 0.92) and increased household income (OR = 0.82, 95% CI 0.79, 0.84).

Procedure Specific Incidence

Using CCS procedure codes for principal procedures, we analyzed the frequency distribution of various surgical procedures in the list of procedures complicated by postoperative sepsis. Gastrointestinal, cardiovascular, or thoracic procedures accounted for 48.7% of cases with postoperative sepsis. We also selected 15 groups of major surgical procedures and calculated rates of postoperative sepsis in each group. To compare these rates, we performed case-mix adjustment by age, race, gender, hospital bed size, hospital location and teaching status, and patient income. Computed risk-adjusted rates of postoperative sepsis were calculated and these groups were re-ranked (Table 3). As shown on Figure 1, groups with rates of postoperative sepsis above the mean were esophageal, pancreatic, gastric, small bowel, hepatic, and biliary procedures. Breast and thyroid procedures had the lowest rates of postoperative sepsis.

Mortality

We examined in-hospital mortality after postoperative sepsis in the same groups of major surgical procedures (Table 3). Patients undergoing thoracic procedures had the highest risk-adjusted rate of death among patients that developed sepsis. Figure 2 displays the distribution of risk-adjusted rates of hospital mortality after postoperative sepsis for major surgical procedures. Four groups that had sepsis rates above mean rate (esophageal, pancreatic, gastric, and hepatic procedures) had also risk-adjusted mortality rates above mean rate. However, mortality rates after cardiac, vascular, adrenal, and splenic procedures complicated by postoperative sepsis rose above mean rate although the incidence rate for sepsis in these groups was below the mean rate. For the entire cohort of patients who developed sepsis after elective surgery, hospital mortality was significantly higher compared with patients not developing postoperative sepsis (25.88% vs. 0.81%, $P < 0.0001$).

Hospital Resource Utilization

Hospital resource utilization was analyzed in patients with and without postoperative sepsis. Median total hospital LOS (length of stay) after surgical procedures complicated by sepsis (18 days) was 3 times greater than after non-complicated procedures (6 days; $P < 0.0001$). A

3.3-fold increase in total hospital cost in cases complicated by postoperative sepsis was noted, from \$17,229 (median) to \$57,032; $P < 0.0001$. Table 4 demonstrates the increase in hospital LOS and cost in each group of examined surgical procedures. In the total cohort, the complication of elective surgical procedures by sepsis increased the total hospital cost by an estimated \$3.83 billion during the study period.

Discussion

We have described the rates of sepsis and the associated mortality for a variety of hospital based surgical procedures. Esophageal, pancreatic, and gastric procedures represented the greatest risk for the development of sepsis, but mortality for patients developing sepsis was found to be the greatest following thoracic, adrenal, and hepatic procedures. Furthermore, we have demonstrated that older patients, men, and non-whites were more likely to develop sepsis as a complication after elective surgery. Our analysis further demonstrates that sepsis is an extremely costly complication to the health care system. Based on the frequency of cases performed, decreasing septic complications after cardiac and colorectal procedures may be the most cost advantageous to the health care system. To our knowledge, this is the largest population-based analysis evaluating the rates, risk factors, mortality, and cost associated with postoperative sepsis following elective surgery.

Previous studies evaluating postoperative sepsis may have limited generalizability due to small study size, single institution experiences, and small geographic regions.²¹⁻²⁷ The incidence of sepsis has increased significantly in the United States over the last decade and has been accompanied by an increase in the severity of sepsis.^{1, 28-29} In the year 2002, The National Healthcare Quality Reports estimated 11.6 cases of post-operative sepsis per 1,000 elective surgery discharges with a hospital length of stay longer than 3 days.² More than 40 million surgical procedures are performed annually in the United States, and despite a reduction in the disease case fatality over time, sepsis remains one of the leading causes of death in the United States.^{1, 4, 29-34}

Our analysis has demonstrated that elective surgical procedures with the highest likelihood of developing sepsis do not necessarily have the greatest mortality. Among elective surgical cases, those with the greatest risk were esophageal, pancreatic, small bowel, and biliary procedures. Of note was the higher than expected rate of septic complications associated with gastric and small bowel cases, even though these procedures have been previously reported as having low septic complications from other large data series.³⁵ Our analysis demonstrates that gastric and small bowel procedures appear to pose a significant risk for the development of postoperative sepsis which may be secondary to disease processes not analyzed in this study. After case-mix adjustment, thoracic, adrenal, and hepatic procedures ranked among the top procedures associated with the highest mortality if sepsis developed. The mortality rates for these procedures were higher than after esophageal and pancreatic procedures. In accordance with our findings, a population level analysis from the UK concluded that the greatest mortality rates were associated with general abdominal procedures.³⁶

Beyond procedure type, we have defined the sociodemographics of postoperative sepsis after elective surgery. Previous large population analyses have evaluated global sepsis rates (medical and surgical combined) and have demonstrated that the incidence of sepsis disproportionately increased in elderly adults, and age was an independent predictor of mortality.³⁷ After adjustment of this cohort for comorbidities, the aged still remained more likely to develop sepsis and had increased mortality after developing sepsis than younger patients. In addition, gender disparities in the occurrence of postoperative sepsis were demonstrated. Women were found to be less likely to develop post operative cases in the

total surgical cohort. Multiple studies have evaluated the correlation of gender to the development of sepsis.³⁸⁻⁴¹ Mechanistic reasons for this gender disparity remain unclear, but further analyses from a population level may provide insight into comorbidities and other factors increasing the likelihood of developing post-operative sepsis.

We have also demonstrated that ethnicity and income have a significant impact on the development of postoperative sepsis. Previous population level investigations have demonstrated a substantial relationship of race and income on mortality and use of services among Medicare beneficiaries.⁴²⁻⁴³ In our adjusted model, we have demonstrated that white race and greater income lessened the likelihood for the development of postoperative sepsis. Reasons for this finding remain unclear, but authors have suggested this may be secondary to educational level, access to care, or the extent of disease when treated.⁴⁴ As well, other authors have demonstrated increased PSI rates in minorities and have suggested that patient race may influence the risk of experiencing a patient safety event. The authors suggested patient risk factors or the organizational characteristics of hospitals may affect quality of care and the occurrence of PSIs.⁴⁵

We have also described institutional characteristics associated with the development of postoperative sepsis after elective surgery. Hospital quality has been previously shown to vary by geographic region and hospital characteristics.⁴⁶ We determined that patients in larger hospitals were more likely to develop sepsis than in smaller hospitals. We also found that elective surgical procedures in urban and non-teaching hospitals were more likely to be complicated by postoperative sepsis. These findings suggest that factors contained within healthcare delivery systems may be associated with the development of postoperative sepsis. Others have suggested that improved outcomes at teaching hospitals may be secondary to increased teaching intensity and better rescue after complications develop, rather than fewer overall complications.⁴⁷ Importantly, the structure and process of care within hospitals have been found to have a significant association with the prevention of surgical site infections.⁴⁸ Khuri et al. has also noted the importance of complications utilizing the National Surgical Quality Improvement Program (NSQIP) database. The occurrence of 30-day postoperative complications were more important than preoperative patient risk and intraoperative factors in determining the survival after major surgery. This suggests that process improvements should be directed toward the prevention of postoperative complications.⁴⁹

Finally, comparison of our findings utilizing the NIS to other large data other large data sets show similar rates of sepsis as a complication of elective procedures. Fowler et al. evaluated the Society of Thoracic Surgeons National Cardiac Database to evaluate clinical predictors of major infections after cardiac surgery.⁵⁰ This study reported a postoperative septicemia rate of approximately 1.23% which was a subset of cardiac patients in which major infection occurred. This rate appears similar to the risk adjusted rate of sepsis of 1.11% found in this analysis. Based upon our analysis, cardiac and colorectal surgery may be future targets for intervention as the frequency of these procedures and the associated cost of sepsis may have a larger impact on limiting cost and expenditure associated with sepsis as a complication.

This study has several limitations. Administrative data originally were intended primarily for reimbursement, although multiple studies have validated the use of administrative data for research purposes.^{1, 51} The potential for inclusion bias based on limited coding schemes for the many clinical entities cannot be entirely excluded as well as the differentiation of comorbidities from chronic illnesses. It is possible that changes in rates of sepsis results may have occurred over time secondary to more complete capturing of codes by institutions based upon reimbursement. An inherent weakness of the study is the reliance upon ICD-9 discharge coding which may vary from institution to institution and within the same institution. Although the code scheme remained constant throughout the study, there may be

coding variations between institutions and this cannot be evaluated from the data set. There may also be a bias in the definition of sepsis as a revised consensus sepsis definitions have been published during the study period which may lead to variation in the severity and classification of sepsis.⁵² There is also an inherent limitation by selecting patients having procedures performed within the first two days of admission, but this was performed to ensure that patients had elective admissions as well as elective procedures. There are limitations using administrative data on millions of patients compared to the use of smaller cohorts with more refined clinical information, but we propose that the present data from an epidemiological standpoint is valuable for future interventions and analysis.

In conclusion, we have identified several elective surgical procedures that demonstrate a greater risk for the development of postoperative sepsis. We have further defined procedures associated with the greater mortality after sepsis develops. We have also noted disparities in the occurrence of sepsis on a population level with regard to patient demographics and institutional characteristics. We have identified opportunities among several high-volume elective procedures where both improved clinical outcome and reduced costs could provide societal benefits. Further focused studies and root cause analyses will be required to decrease the rates of postoperative sepsis and delineate targets for process level improvements.

Acknowledgments

TRV is supported in part by the American Heart Association ID: 0980011N

SFL is supported in part by the National Institute of General Medical Sciences: RO1 GM 34695

References

1. Martin GS, Mannino DM, Eaton S, Moss M. The epidemiology of sepsis in the United States from 1979 through 2000. *N Engl J Med* Apr 17;2003 348(16):1546–1554. [PubMed: 12700374]
2. Agency for Healthcare Research and Quality. 2005 National Healthcare Quality Report. Rockville, MD: U.S. Department of Health and Human Services, Agency for Healthcare Research and Quality; [Accessed April 7, 2008]. Dec2005 AHRQ Pub. No. 06-0018 2005; <http://www.ahrq.gov/qual/nhrq05/fullreport/>
3. Vogel TR, Dombrovskiy VY, Lowry SF. Trends in postoperative sepsis: are we improving outcomes? *Surgical infections* Feb;2009 10(1):71–78. [PubMed: 19298170]
4. Anderson RN, Smith BL. Deaths: leading causes for 2002. *Natl Vital Stat Rep* Mar 7;53(17):1–89.
5. Allison JJ, Weissman NW, Silvey AB, Chapin CA, Kiefe CI. Identifying top-performing hospitals by algorithm: results from a demonstration project. *Jt Comm J Qual Patient Saf* Jun;2008 34(6):309–317. [PubMed: 18595376]
6. Alsac JM, Desgranges P, Kobeiter H, Becquemin JP. Emergency endovascular repair for ruptured abdominal aortic aneurysms: feasibility and comparison of early results with conventional open repair. *Eur J Vasc Endovasc Surg* Dec;2005 30(6):632–639. [PubMed: 16061405]
7. Russo, CA.; Andrews, RM. Agency for Healthcare Research and Quality; Rockville, MD: [Accessed February 1, 2007]. 2006 The National Hospital Bill: The Most Expensive Conditions, by Payer, 2004. HCUP Statistical Brief # 13. September 2006 <http://www.hcup-us.ahrq.gov/reports/statbriefs/sb13.pdf>
8. HCUP Nationwide Inpatient Sample (NIS). Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality; Rockville, MD: [Accessed March 15, 2008]. www.hcup-us.ahrq.gov/nisoverview.jsp
9. Etzioni DA, Mack TM, Beart RW Jr, Kaiser AM. Diverticulitis in the United States: 1998-2005: changing patterns of disease and treatment. *Annals of surgery* Feb;2009 249(2):210–217. [PubMed: 19212172]

10. Agency for Healthcare Research and Quality. Patient Safety Indicators: Technical Specifications. Ver. 3.2 [Accessed March 15, 2008]. Mar2008 2008; http://www.qualityindicators.ahrq.gov/downloads/psi/psi_technical_specs_v32.pdf
11. Guide to Patient Safety Indicators. codes in Appendix O and P of the PSI Technical Specifications. Version 3.1 [March 12, 2007]. 2009 <http://www.qualityindicators.ahrq.gov/>
12. Vogel TR, Dombrovskiy VY, Haser PB, Scheirer JC, Graham AM. Outcomes of carotid artery stenting and endarterectomy in the United States. *J Vasc Surg* Feb;2009 49(2):325–330. discussion 330. [PubMed: 19058948]
13. Elixhauser A, Pancholi M, Clancy CM. Using the AHRQ quality indicators to improve health care quality. *Jt Comm J Qual Patient Saf* Sep;2005 31(9):533–538. [PubMed: 16255332]
14. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* Jan;1998 36(1):8–27. [PubMed: 9431328]
15. Li B, Evans D, Faris P, Dean S, Quan H. Risk adjustment performance of Charlson and Elixhauser comorbidities in ICD-9 and ICD-10 administrative databases. *BMC Health Serv Res* 2008;8:12. [PubMed: 18194561]
16. Using the HCUP Nationwide Inpatient Sample to Estimate Trends. [Accessed August 2005]. HCUP Methods SeriesReport # 2005-1. http://www.hcup-us.ahrq.gov/reports/TrendReport2005_1.pdf
17. Wray NP, Hollingsworth JC, Peterson NJ, Ashton CM. Case-mix adjustment using administrative databases: a paradigm to guide future research. *Med Care Res Rev* Sep;1997 54(3):326–356. [PubMed: 9437171]
18. Harris AD, McGregor JC. The importance of case-mix adjustment for infection rates and the need for more research. *Infect Control Hosp Epidemiol* Aug;2008 29(8):693–694. [PubMed: 18643745]
19. Mehta RH, Liang L, Karve AM, et al. Association of patient case-mix adjustment, hospital process performance rankings, and eligibility for financial incentives. *Jama* Oct 22;2008 300(16):1897–1903. [PubMed: 18940976]
20. U.S. Bureau of Labor Statistics. CPI Inflation Calculator. [Accessed July 1, 2009]. www.bls.gov/data/inflation_calculator.htm
21. Barnes BA, Behringer GE, Wheelock FC, Wilkins EW. Postoperative sepsis: trends and factors influencing sepsis over a 20-year period reviewed in 20,000 cases. *Annals of surgery* Oct;1961 154:585–598. [PubMed: 13865084]
22. Pittet D, Rangel-Frausto S, Li N, et al. Systemic inflammatory response syndrome, sepsis, severe sepsis and septic shock: incidence, morbidities and outcomes in surgical ICU patients. *Intensive Care Med* Apr;1995 21(4):302–309. [PubMed: 7650252]
23. Farinas-Alvarez C, Farinas MC, Fernandez-Mazarrasa C, Llorca J, Casanova D, Delgado-Rodriguez M. Analysis of risk factors for nosocomial sepsis in surgical patients. *The British journal of surgery* Aug;2000 87(8):1076–1081. [PubMed: 10931054]
24. Slotman GJ. Prospectively validated predictions of shock and organ failure in individual septic surgical patients: the Systemic Mediator Associated Response Test. *Crit Care* 2000;4(5):319–326. [PubMed: 11056759]
25. Farinas-Alvarez C, Farinas MC, Prieto D, Delgado-Rodriguez M. Applicability of two surgical-site infection risk indices to risk of sepsis in surgical patients. *Infect Control Hosp Epidemiol* Oct;2000 21(10):633–638. [PubMed: 11083178]
26. Bellomo R, Goldsmith D, Russell S, Uchino S. Postoperative serious adverse events in a teaching hospital: a prospective study. *The Medical journal of Australia* Mar 4;2002 176(5):216–218. [PubMed: 11999237]
27. Mokart D, Leone M, Sannini A, et al. Predictive perioperative factors for developing severe sepsis after major surgery. *British journal of anaesthesia* Dec;2005 95(6):776–781. [PubMed: 16227337]
28. Dombrovskiy VY, Martin AA, Sunderram J, Paz HL. Facing the challenge: Decreasing case fatality rates in severe sepsis despite increasing hospitalizations. *Crit Care Med* Nov;2005 33(11):2555–2562. [PubMed: 16276180]
29. Dombrovskiy VY, Martin AA, Sunderram J, Paz HL. Rapid increase in hospitalization and mortality rates for severe sepsis in the United States: a trend analysis from 1993 to 2003. *Crit Care Med* May;2007 35(5):1244–1250. [PubMed: 17414736]

30. Improving America's Hospitals. The Joint Commission's Annual Report on Quality and Safety. [Accessed April 22, 2008]. 2007
http://www.jointcommissionreport.org/pdf/JC_2007_Annual_Report.pdf
31. 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* Feb;1993 14(2):73-80. [PubMed: 8440883]
32. Bruce J, Russell EM, Mollison J, Krukowski ZH. The measurement and monitoring of surgical adverse events. *Health technology assessment (Winchester, England)* 2001;5(22):1-194.
33. Fry DE, Fry RV. Surgical site infection: the host factor. *Aorn J* Nov;2007 86(5):801-810. quiz 811-804. [PubMed: 18050889]
34. Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR. Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. *Crit Care Med* Jul;2001 29(7):1303-1310. [PubMed: 11445675]
35. Margenthaler JA, Longo WE, Virgo KS, et al. Risk factors for adverse outcomes following surgery for small bowel obstruction. *Ann Surg* Apr;2006 243(4):456-464. [PubMed: 16552195]
36. Pearse RM, Harrison DA, James P, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006;10(3):R81. [PubMed: 16749940]
37. Martin GS, Mannino DM, Moss M. The effect of age on the development and outcome of adult sepsis. *Crit Care Med* Jan;2006 34(1):15-21. [PubMed: 16374151]
38. Schroder J, Kahlke V, Staubach KH, Zabel P, Stuber F. Gender differences in human sepsis. *Arch Surg* Nov;1998 133(11):1200-1205. [PubMed: 9820351]
39. May AK, Dossett LA, Norris PR, et al. Estradiol is associated with mortality in critically ill trauma and surgical patients. *Crit Care Med* Jan;2008 36(1):62-68. [PubMed: 18090358]
40. Choudhry MA, Bland KI, Chaudry IH. Gender and susceptibility to sepsis following trauma. *Endocr Metab Immune Disord Drug Targets* Jun;2006 6(2):127-135. [PubMed: 16787286]
41. Choudhry MA, Bland KI, Chaudry IH. Trauma and immune response--effect of gender differences. *Injury* Dec;2007 38(12):1382-1391. [PubMed: 18048037]
42. Gornick ME, Eggers PW, Reilly TW, et al. Effects of race and income on mortality and use of services among Medicare beneficiaries. *N Engl J Med* Sep 12;1996 335(11):791-799. [PubMed: 8703185]
43. Heisler M, Smith DM, Hayward RA, Krein SL, Kerr EA. Racial disparities in diabetes care processes, outcomes, and treatment intensity. *Med Care* Nov;2003 41(11):1221-1232. [PubMed: 14583685]
44. Feinglass J, Abadin S, Thompson J, Pearce WH. A census-based analysis of racial disparities in lower extremity amputation rates in Northern Illinois, 1987-2004. *J Vasc Surg* May;2008 47(5):1001-1007. discussion 1007. [PubMed: 18358670]
45. Shimada, SLM-RM.; Loveland, SA., et al. Racial Disparities in Patient Safety Indicator (PSI) Rates in the Veterans Health Administration. 2009.
http://www.ahrq.gov/downloads/pub/advances2/vol1/Advances-Shimada_65.pdf
46. Baicker K, Chandra A, Skinner JS. Geographic variation in health care and the problem of measuring racial disparities. *Perspect Biol Med* 2005 Winter;48(1 Suppl):S42-53. [PubMed: 15842086]
47. Silber JH, Rosenbaum PR, Romano PS, et al. Hospital teaching intensity, patient race, and surgical outcomes. *Arch Surg* Feb;2009 144(2):113-120. discussion 121. [PubMed: 19221321]
48. Campbell DA Jr. Henderson WG, Englesbe MJ, et al. Surgical site infection prevention: the importance of operative duration and blood transfusion--results of the first American College of Surgeons-National Surgical Quality Improvement Program Best Practices Initiative. *J Am Coll Surg* Dec;2008 207(6):810-820. [PubMed: 19183526]
49. Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* Sep;2005 242(3):326-341. discussion 341-323. [PubMed: 16135919]

50. Fowler VG Jr, O'Brien SM, Muhlbaier LH, Corey GR, Ferguson TB, Peterson ED. Clinical predictors of major infections after cardiac surgery. *Circulation* Aug 30;2005 112(9 Suppl):I358–365. [PubMed: 16159846]
51. Krumholz HM, Wang Y, Mattera JA, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. *Circulation* Apr 4;2006 113(13):1683–1692. [PubMed: 16549637]
52. Weiss M, Huber-Lang M, Taenzer M, et al. Different patient case mix by applying the 2003 SCCM/ESICM/ACCP/ATS/SIS sepsis definitions instead of the 1992 ACCP/SCCM sepsis definitions in surgical patients: a retrospective observational study. *BMC medical informatics and decision making* 2009;9:25. [PubMed: 19450242]

Ann Surg. Author manuscript; available in PMC 2011 December 1.

Figure 2.
Risk-adjusted rates of hospital mortality after postoperative sepsis for groups of major surgical procedures (*error bar*, 95% CI).

Table 1

ICD-9-CM procedure codes for major groups of surgical procedures

Groups of surgical procedures	ICD-9-CM procedures codes
Esophageal surgery	42.0x, 42.1x, 42.31, 42.32, 42.39, 42.4x, 42.58, 42.59, 42.61, 42.62, 42.69, 42.7, 42.82-42.85, 42.89
Pancreatic surgery	52.0x, 52.22, 52.3, 52.4, 52.5x, 52.6, 52.7, 52.95, 52.96
Small bowel surgery	45.00-45.02, 45.31-45.33, 45.51, 45.61-45.63, 45.91,
Gastric surgery	43.0, 43.3, 43.5-43.7, 43.8x, 43.9x, 44.0x, 44.31, 44.39, 44.40-44.42, 44.5, 44.61, 44.63, 44.66-44.69, 44.91, 44.92, 44.95-44.99
Splenic surgery	41.1, 41.2, 41.4x, 41.5, 41.93, 41.95, 41.99
Gallbladder surgery	51.02, 51.03, 51.04, 51.2x, 51.31, 51.32, 51.36-51.39, 51.4x, 51.5x, 51.61-51.63, 51.69, 51.7x, 51.81, 51.91-51.94
Hepatic surgery	50.0, 50.2x, 50.3, 50.6x
Vascular surgery	38.11, 38.12, 38.34, 38.35, 38.44, 38.45, 38.64, 38.08, 38.18, 38.38, 38.48, 38.88, 39.25, 39.29, 39.71, 39.73
Adrenal surgery	07.2x, 07.3, 07.4x, 07.52-07.59
Colorectal surgery	45.03, 45.52, 45.7x, 45.8x, 45.94, 45.95, 46.1x, 48.0, 48.1, 48.35, 48.41, 48.49, 48.5x, 48.6x, 48.7x
Thoracic surgery	32.20-32.26, 32.29, 32.3x, 32.4x, 32.5x
Cardiac surgery	35.0x, 35.1x, 35.2x, 35.96, 35.99, 36.1x, 36.2, 36.3x
Hernia surgery	53.0x, 53.1x, 53.2x, 53.3x, 53.41, 53.49, 53.5x, 53.61, 53.69, 53.7x, 53.80-53.82, 53.9
Thyroidectomy	06.0x, 06.2, 06.3x, 06.4, 06.5x, 06.6, 06.7, 06.8x, 06.9x
Breast surgery	85.4x

Table 2

Sociodemographic characteristics of patients in the research cohort.

Characteristic	Estimated cohort		Patients with sepsis	
	# of patients	% *	# of patients	% **
Estimated Total	6,512,921	100	78,669	1.21
Age, years:				
18-49	1,220,515	18.74	10,255	0.84
50-64	1,946,096	29.88	20,208	1.04
65-79	2,535,898	38.94	34,879	1.38
80 and above	810,412	12.44	13,327	1.64
Gender:				
Males	2,916,735	44.79	41,894	1.44
Females	3,594,923	55.21	36,759	1.02
Missed	1,263		16	
Race:				
White, non-Hispanic	3,647,602	82.11	43,498	1.19
Black, non-Hispanic	393,163	8.85	6,002	1.53
Hispanic	240,915	5.42	3,442	1.43
Other	160,599	3.62	2,242	1.40
Missed	2,070,642		23,485	
Insurance status:				
Medicare	3,359,890	51.66	49,960	1.49
Medicaid	325,924	5.01	4,761	1.46
Private	2,468,364	37.94	20,770	0.84
Other	235,242	3.62	1,936	0.82
Uninsured	114,849	1.77	1,165	1.01
Missed	8,652		77	

* Frequency distribution within each characteristic

** Percentage of patients with sepsis among all patients in this column

Table 3

Case-mix adjusted rates of postoperative sepsis and mortality in major groups of surgical procedures.

Groups of surgical procedures	Incidence rates of sepsis, %				Mortality rates, %			
	With sepsis			rank	Without sepsis			Rank
	mean	95% CI	rank		mean	95% CI	rank	
Esophageal surgery	3.84	3.54,4.13	1	1	33.43	30.11, 36.76	4	1
Pancreatic surgery	3.17	2.98,3.35	2	2	31.93	29.31, 34.54	6	2
Gastric surgery	2.84	2.76,2.92	3	3	33.12	31.61, 34.63	5	3
Small bowel surgery	2.75	2.61, 2.89	4	4	23.96	21.83,26.08	11	8
Gallbladder surgery	1.80	1.70, 1.90	5	5	18.68	16.64, 20.73	13	10
Hepatic surgery	1.74	1.59,1.89	6	6	36.37	32.48, 40.25	3	4
Splenic surgery	1.59	1.38, 1.81	7	7	29.68	24.09, 35.27	9	7
Adrenal surgery	1.48	1.20, 1.76	8	8	39.60	29.24, 49.96	2	11
Vascular surgery	1.40	1.35, 1.44	9	9	31.63	30.15, 33.11	7	9
Colorectal surgery	1.19	1.16, 1.22	10	10	24.50	23.50, 25.49	10	12
Cardiac surgery	1.11	1.09, 1.14	11	11	30.79	29.65, 31.94	8	6
Thoracic surgery	0.99	0.95, 1.04	12	12	45.90	43.83, 47.97	1	5
Hernia surgery	0.84	0.78, 0.90	13	13	22.99	20.18, 25.80	12	14
Thyroidectomy	0.49	0.37, 0.61	14	14	7.30	0.92, 13.69	15	13
Breast surgery	0.29	0.23, 0.35	15	15	16.43	8.81, 24.05	14	15

Frequency, Hospital length of stay, and Cost Adjusted to 2006 for various surgical procedures with and without postoperative sepsis.

Table 4

Surgical procedures	Frequency	LOS, days (median)			Cost, \$\$ (median)		
		w/o sepsis	with sepsis	P	w/o sepsis	with sepsis	P
Cardiac surgery	653,481	6	19	<0.0001	27474	75548	<0.0001
Colorectal surgery	534,151	6	18	<0.0001	11,701	46177	<0.0001
Vascular surgery	259,728	6	16	<0.0001	16,281	53,786	<0.0001
Thoracic surgery	182,394	6	18	<0.0001	15,714	55,874	<0.0001
Gastric surgery	151,543	5	20	<0.0001	14,326	61,428	<0.0001
Hernia surgery	94,562	5	14	<0.0001	9,711	38,129	<0.0001
Gallbladder surgery	64,918	5	14	<0.0001	11,227	36,460	<0.0001
Small bowel surgery	50,239	7	19	<0.0001	12,803	48,596	<0.0001
Pancreatic surgery	35,955	9	24	<0.0001	20,591	66,527	<0.0001
Breast surgery	33,639	4	6	0.0026	11,810	15,927	0.0294
Hepatic surgery	28,584	6	18	<0.0001	17,055	55,308	<0.0001
Esophageal surgery	16,117	9	27	<0.0001	23,126	80,349	<0.0001
Thyroidectomy	13,265	5	18	0.0007	11,051	64,689	0.0003
Splenic surgery	13,220	5	13	<0.0001	12,026	48,238	<0.0001
Adrenal surgery	7,125	5	14	0.0002	12,903	46,341	<0.0001