Infectious complications after elective vascular surgical procedures

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Objective: **This study was conducted to evaluate and compare the rates of postoperative infectious complications and death after elective vascular surgery, define vascular procedures with the greatest risk of developing nosocomial infections, and assess the effect of infection on health care resource utilization.**

Methods: **The Nationwide Inpatient Sample (2002-2006) was used to identify major vascular procedures by International Classification of Diseases, 9th Clinical Modification (ICD-9-CM) codes. Infectious complications identified included pneumonia, urinary tract infections (UTI), postoperative sepsis, and surgical site infections (SSI). Case-mix-adjusted rates were calculated using a multivariate logistic regression model for infectious complication or death as an outcome and indirect standardization.**

Results: **A total of 870,778 elective vascular surgical procedures were estimated and evaluated with an overall postoperative infection rate of 3.70%. Open abdominal aortic surgery had the greatest rate of postoperative infections, followed by open thoracic procedures and aorta-iliac-femoral bypass. Thoracic endovascular aneurysm repair (TEVAR) infectious complication rates were two times greater than after EVAR ($P < .0001$). Pneumonia was the most common infectious complication after open aortic surgery (6.63%). UTI was the most common after TEVAR (2.86%) and EVAR (1.31%). Infectious complications were greater in octogenarians ($P < .0002$), women ($P < .0001$), and blacks ($P < .0001$ vs whites and Hispanics). Nosocomial infections after elective vascular surgery significantly increased hospital length of stay (13.8 ± 15.4 vs 3.5 ± 4.2 days; $P < .001$) and reported total hospital cost ($37,834 ± $42,905 vs $11,851 ± $11,816; $P < .001$).**

Conclusions: **Elective vascular surgical procedures vary widely in the estimated risk of postoperative infection. Open aortic surgery and endarterectomy of the head and neck vessels have, respectively, the greatest and the lowest reported incidence for postoperative infectious complications. Women, octogenarians, and blacks have the highest risk of infectious complications after elective vascular surgery. Disparities in the development of infectious complications on a systems level were also found in larger hospitals and teaching hospitals. Hospital infectious complications were found to significantly increase health care resource utilization. Strategies that reduce nosocomial complications and target high-risk procedures may offer significant future cost savings. (J Vasc Surg 2010;51:122-30.)**

Previous reports have demonstrated that the occurrence of postoperative complications are more significant than preoperative patient risk and intraoperative factors in determining patient survival after major surgery.[1] Population-level studies examining complications after elective surgery have demonstrated that the rates of sepsis have increased significantly during the last decade, with a little improvement in mortality.[2] Substantial cost is associated with postoperative complications due to inferior patient outcomes and increased hospital resource utilization.[3] As the health care system focuses more on pay for performance, analyses evaluating infectious complications after common elective vascular surgical procedures may offer insight for quality improvement and improved patient outcomes.[4]

Few large population studies have evaluated infection and sepsis rates after elective vascular surgery that is generalizable to the nation at large. The objective of this study was to evaluate and compare the rates of postoperative infectious complications and mortality after major elective vascular surgical procedures, to define procedures with the greatest risk of developing nosocomial infections, and to assess the effect of infection on health care resource utilization. Improvements in decreasing infectious complications in high-risk vascular procedures may assist in creating initiatives to improve patient outcomes and decrease hospital costs associated with elective vascular surgery.

METHODS

Data sources. Study data were collected from the Nationwide Inpatient Sample (NIS) from the year 2002 to 2006. This is the largest all-payer hospital database in the United States (U.S.), developed as part of the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (AHRQ). The NIS data set that we used represents a sampling of all hospital inpatient stays from about 1000 hospitals in 38 states. It includes a 20% sample of the United States for all nonmilitary hospitalizations.

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Hospitals are stratified by characteristics, including bed size, teaching status, urban or rural location, and U.S. region "with sampling probabilities proportional to the number of U.S. hospitals in each stratum."[5] This sampling technique allows national estimates to be computed. By HCUP definitions, a metropolitan statistical area is considered urban, and a nonmetropolitan statistical area is rural. Teaching hospitals have an American Medical Association-approved residency program or have membership in the Council of Teaching Hospitals. Bed size categories are based on hospital beds and are specific to the hospital's region, location, and teaching status by HCUP methodology.[6]

The database is a weighted probability sample intended to provide national estimates of all U.S. hospital admissions. Sampling strata were used to create the NIS based on five hospital characteristics to be representative of the U.S. population. Sampling weights are provided to account for the complex survey design and to provide national estimates. The weighting function methodology provided by HCUP was used to weight the stratified sample to represent estimates of the entire U.S. patient population undergoing major elective surgical procedures in the country. All data and analyses from the NIS were analyzed and are reported using the weighting methodology defined by the NIS.[6,7]

Study population. Patients aged ≥18 years undergoing eight major hospital-based surgical vascular procedures after only elective admission were selected. Classification as elective vs nonelective was based on the HCUP variable for admission type. The following International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes were used:

- 38.12—for endarterectomy of head and neck vessels;
- 38.34, 38.44, and 38.64—for open abdominal aortic repair;
- 38.35 and 38.45—for open thoracic vascular resection and replacement, which includes thoracoabdominal aortic repair;
- 39.71—for EVAR;
- 39.73—for TEVAR;
- 39.25—for aorta-iliac-femoral bypass;
- 39.29, 38.88, 38.48, and 38.38—for peripheral vascular bypass; and
- 38.08 and 38.18—for embolectomy and endarterectomy of lower limbs.

Cases with ICD-9-CM procedure codes for two or more of these vascular procedures were excluded from the analysis. We excluded cases with infection diagnosis-related group (DRG), ICD-9-CM infection diagnosis contained in the principal diagnosis, and ICD-9-CM diagnosis or procedures codes for immunocompromised states in any diagnosis or procedure position. This methodology is recommended by the AHRQ Patient Safety Indicator (PSI) number 13 "Postoperative Sepsis" to identify the "problems that patients experience as a result of exposure to the healthcare system and that are likely amenable to prevention by changes at the system or provider level. These are referred to as complications or adverse events."[8]

To select patients with postoperative sepsis, we used the AHRQ PSI SAS software that includes indicator "Postoperative sepsis" (PSI-13).[8] Using the same approach, we also identified patients with postoperative pneumonia (997.3, 482.0-482.2, 482.3x, 482.4x, 482.81-482.83, 482.89, 482.9); urinary tract infection, (UTI; 599.0, 996.64); and surgical site infection (SSI; 998.31, 998.32, 998.5x). Because hospital stay is the unit of observation in the NIS data set and there are no identifiers, longitudinal analysis was not performed, and only postoperative complications developing during the index admission are presented.

The Elixhauser Index[9-11] was used to identify and adjust for comorbidities in the cohort. The NIS data includes 29 AHRQ comorbidity measures reported by Elixhauser et al.[10] To identify these comorbidities, we used the Comorbidity Software developed as part of the Healthcare Cost and Utilization Project (HCUP).[12] The performance of the Elixhauser comorbidity measures in predicting patient outcomes are validated and have been established in the prediction of in-hospital and 1-year mortality.[11] These comorbidities are coded in the data as 1 (yes) or 0 (no). For case-mix adjustment, we included the following comorbidities appropriate for vascular surgery: hypertension, congestive heart failure, chronic pulmonary disease, diabetes with chronic complications, diabetes without chronic complications, and renal failure.

Statistical analysis. SAS 9.2 software (SAS Institute, Cary, NC) was used for all data analysis, including statistics. The difference between groups was analyzed with χ^2 analysis for categoric variables and the *t* test for continuous variables. Crude rates of postoperative infections were calculated by dividing the number of observations with infection (total or with specific infection) by the number of all observations and expressed as a percentage. Crude rates for mortality were calculated by dividing the number of fatalities by the total number of patients in each group and also expressed as a percentage.

Risk-adjusted rates of postoperative infection and mortality for each procedure were calculated. To perform this, the expected rates for each procedure were calculated using a logistic regression model created with infection or death as the dependent variable (outcome), and the independent variables were identified as predictors of this outcome (patient age, gender, and race; selected AHRQ comorbidities; hospital bed size, and hospital teaching status). 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. After 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 epidemiologic studies to calculate case-mix–adjusted rates.[13-21]

Table I. Sociodemographic characteristics of patients

Characteristic	*Whole cohort* No. (%)[a]	*Patients with infection* No. (%)[b]
Total	870,778 (100)	32,197 (3.70)
Age, years		
18-49	32,744 (3.76)	1280 (3.91)
50-64	218,139 (25.05)	6986 (3.20)
65-79	469,924 (53.97)	17,484 (3.72)
≥80	149,971 (17.22)	6447 (4.30)
Gender		
Males	533,780 (61.30)	17,521 (3.28)
Females	336,920 (38.70)	14,676 (4.36)
Missed	78	
Race		
White, non-Hispanic	541,810 (89.03)	19,094 (3.52)
Black, non-Hispanic	32,177 (5.29)	1798 (5.59)
Hispanic	19,531 (3.21)	907 (4.64)
Other	15,027 (2.47)	651 (4.33)
Missed	262,233	9747

[a]Frequency distribution within each characteristic.
[b]Percentage of patients with postoperative infection among all patients in this line.

To transform hospital charges in the data to cost data we used the HCUP Cost-to-Charge Ratio Files, which are hospital-level files designed to supplement the data elements in the NIS database. Means in the text are accompanied by the standard deviations (SD). A value of $P < .05$ was considered to be statistically significant.

RESULTS

We defined 870,778 weighted elective vascular surgical procedures that met our selection criteria. Elective vascular procedures accounted for 73% of all designated vascular surgical procedures. The sociodemographic characteristics of patients in the cohort are reported in Table I. In the entire study cohort, 71.2% of patients were elderly (age ≥65 years), <4% were younger than 50 years, men predominated over women ($P < .0002$), and almost 90% of the study population with an identified race was white.

Overall, postoperative infections were reported in 3.7% of patients after elective vascular surgery. The postoperative infection rate steadily increased from age 50 years and peaked at a rate of 4.3% in octogenarians. Univariate analysis demonstrated infections were more likely to develop in women than men (odds ratio [OR], 1.34; 95% confidence interval [CI], 1.31-1.37) and that whites had the lowest infection rates compared with blacks. Postoperative infection developed more often in Hispanics than in whites (OR, 1.33; 95% CI, 1.24-1.43), but blacks remained more likely to present with infections than Hispanics (OR, 1.22; 95% CI, 1.12-1.32). Postoperative infection was 1.6 times (95% CI, 1.54-1.70) more likely to occur in blacks than in whites.

Univariate analysis was used to calculate the rates of postoperative infection after elective vascular procedures in association with hospital characteristics. An infection after elective vascular procedures was more likely to occur in an urban hospital than in a rural hospital (OR, 1.8; 95% CI, 1.04-1.13). Similarly, patients in large hospitals exhibited a higher incidence of postoperative infectious complications vs patients in medium (OR, 1.04; 95% CI, 1.008-1.064) and small (OR, 1.19; 95% CI, 1.14-1.24) hospitals. Teaching hospitals were 1.18 times (95% CI, 1.16-1.21) as likely to report postoperative infection as nonteaching hospitals.

To adjust the findings of univariate analysis, a logistic regression model with postoperative infection as a binary dependent variable was created and included independent variables that were identified as significant predictors of infection from the univariate analysis. After adjustment, octogenarians remained 1.08 times (95% CI, 1.002-1.157) as likely as younger patients to develop postoperative infections. In multivariable analysis, postoperative infection developed more often in women than in men (OR, 1.42; 95% CI, 1.38-1.46) and more often in blacks (OR, 1.77; 95% CI, 1.68-1.87) and Hispanics (OR, 1.42; 95% CI, 1.33-1.52) than in whites. The likelihood of postoperative infection in teaching hospitals remained greater than in nonteaching (OR, 1.27; 95% CI, 1.23-1.30). Compared with small hospitals, the likelihood was greater in medium (OR, 1.18; 95% CI, 1.11-1.25) and large hospitals (OR, 1.28; 95% CI, 1.22-1.35).

We evaluated risk factors for death in the multivariable logistic regression model with the binary dependent variable for death and the same independent variables as in the model for infection. Death was more likely to occur in patients aged 65 to 79 years (OR, 1.36; 95% CI, 1.17-1.59) and ≥80 years (OR, 1.36; 95% CI, 1.17-1.59) than in the youngest patients. Blacks (OR, 1.36; 95% CI, 1.21-1.52 and Hispanics (OR, 1.34; 95% CI, 1.17-1.54) were also more likely to die than whites. Women, however, were less likely to die than men (OR, 0.92; 95% CI, 0.87-0.97).

Table II reports the crude rates for various postoperative infections after different vascular surgical procedures and the total risk-adjusted infection rate for each procedure. Pneumonia had the highest incidence, especially after open aortic surgical procedures. UTI was the next most frequent infectious complication after open aortic surgical procedures. Open aortic procedures also accounted for the greatest rates of sepsis and SSI. The overall risk-adjusted postoperative infection rates were also greatest after open aortic repairs.

EVAR rates of overall postoperative infection were significantly lower than after open aortic repair ($P < .001$). The differences in postoperative infection rates between open abdominal and thoracic aorta repair were not significant. TEVAR infectious complication rates were doubled compared with EVAR ($P < .0001$). The lowest rate of postoperative infection was found after endarterectomy of the head and neck vessels. Hospital mortality among patients developing infection after elective vascular surgical procedures was significantly greater (Table III).

In the entire study cohort, postoperative infection significantly increased hospital length of stay (LOS) from 3.5 ± 4.2 to 13.8 ± 15.2 days ($P < .0001$). This increase

Table II. Infection rates (%) after various vascular surgical procedures

	Infection groups (crude rate)				*Total (risk-adjusted)*	
Procedures	*PNA*	*UTI*	*Sepsis*	*SSI*	*Mean*	*95% CI*
Open abdominal aortic repair	6.63	2.42	2.06	1.06	11.35	11.19-11.51
Open thoracic aortic repair	6.70	2.48	1.32	1.30	11.29	11.07-11.52
Aorta-iliac-femoral bypass	5.01	2.21	1.34	1.29	8.94	8.81-9.07
Thoracic endovascular aneurysm repair	2.52	2.86	0.58	0.57	5.73	5.34-6.12
Embolectomy and endarterectomy of lower limbs	1.08	1.88	1.05	1.03	4.63	4.56-4.70
Peripheral vascular bypass	0.84	1.82	0.48	1.38	4.19	4.15-4.23
Endovascular aneurysm repair	1.05	1.31	0.26	0.17	2.84	2.81-2.87
Endarterectomy of head and neck vessels	0.63	0.77	0.08	0.08	1.66	1.65-1.67

CI, Confidence interval; *PNA,* pneumonia; *SSI,* surgical site infection; *UTI,* urinary tract infection.

Table III. Risk-adjusted rates of mortality (%) after various vascular surgical procedures

	Without infection		*With infection*	
Procedures	*Mean*	*95% CI*	*Mean*	*95% CI*
Open abdominal aortic repair	2.26	2.211-2.307	7.05	6.578-7.519
Open thoracic aortic repair	4.13	4.002-4.251	7.56	6.842-8.283
Aorta-iliac-femoral bypass	1.49	1.447-1.523	6.78	6.303-7.250
Thoracic endovascular aneurysm repair	2.98	2.554-3.413	. . .[a]	. . .
Embolectomy and endarterectomy of lower limbs	1.26	1.219-1.293	8.83	7.495-10.161
Peripheral vascular bypass	0.52	0.513-0.528	3.09	2.871-3.314
Endovascular aneurysm repair	0.34	0.335-0.346	4.91	4.340-5.481
Endarterectomy of head and neck vessels	0.31	0.307-0.312	3.46	3.186-3.727

CI, Confidence interval.
[a]The number is too small to calculate risk-adjusted rate.

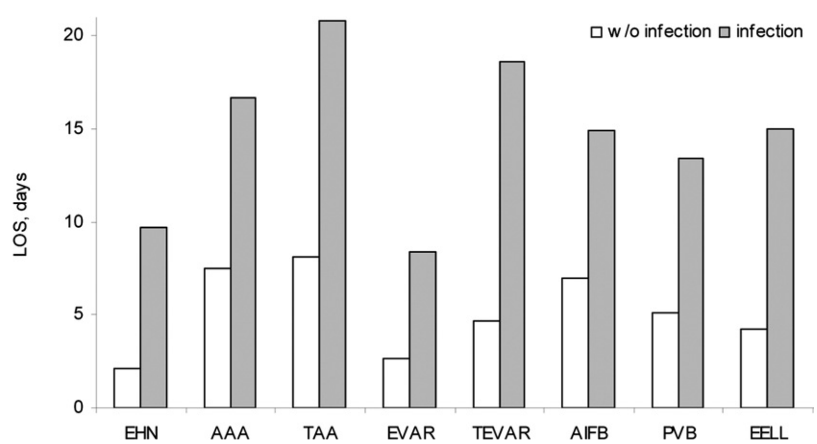

Fig 1. Hospital length of stay is shown after elective surgical vascular procedures with and without postoperative infection. *EHN,* Endarterectomy of vessels of head and neck; *AAA,* abdominal aortic aneurysm repair; *TAA,* thoracic aortic aneurysm repair; *EVAR,* endovascular abdominal aneurysm repair; *TEVAR,* thoracic endovascular aneurysm repair; *AIFB,* aorta-iliac-femoral bypass; *PVB,* peripheral vascular bypass; *EELL,* embolectomy and endarterectomy of lower limb.

was different for various procedures and varied from a 2.1-fold increase after aorta-iliac-femoral bypass to 4.6-fold after endarterectomy of the head and neck vessels (Fig 1). Estimated total hospital costs after elective vascular surgical procedures complicated by postoperative infection also increased from \$12,246 ± \$12,133 to \$38,222 ± \$42,431 ($P < .0001$). The increases in hospital cost by procedure type are shown in Fig 2. This increase varied from 2.2-fold after open abdominal aortic aneurysm (AAA) repair to 3.4-fold after endarterectomy of the head and neck vessels.

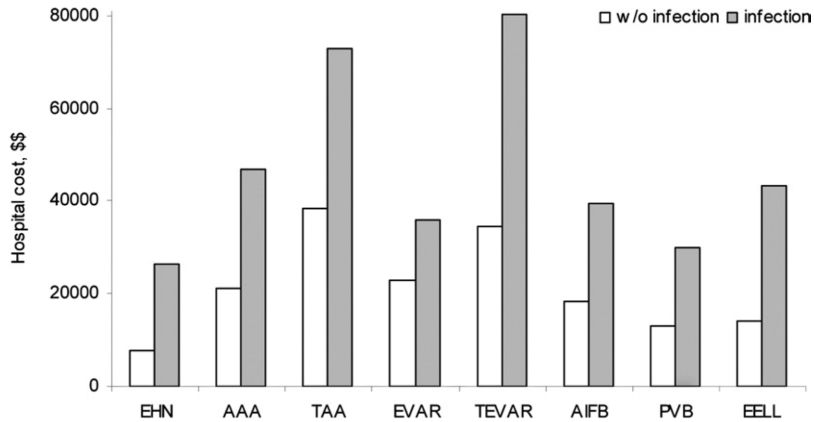

Fig 2. Hospital cost after elective surgical vascular procedures is shown with and without postoperative infection. *EHN,* Endarterectomy of head and neck vessels; *AAA,* abdominal aortic aneurysm repair; *TAA,* thoracic aortic aneurysm repair; *EVAR,* endovascular abdominal aneurysm repair; *TEVAR,* thoracic endovascular aneurysm repair; *AIFB,* aorta-iliac-femoral bypass; *PVB,* peripheral vascular bypass; *EELL,* embolectomy and endarterectomy of lower limb.

DISCUSSION

Current information evaluating postoperative infection and sepsis after elective vascular surgery has been primarily limited to series from single centers. The use of population data to evaluate infectious complications and sepsis on a national level after elective vascular surgery may help to develop preventative strategies for high-risk procedures within the community at large and elucidate rates higher than anticipated for common vascular procedures. Analysis of specific categories of elective vascular procedures, delineation of the types of infections associated by procedure, and the description of hospital characteristics may offer future targets for intervention. Infectious complications may be considered a preventable adverse event and may be a surrogate of quality and outcomes.[22] Despite this information, little information is available to provide national benchmarks for infectious complications after elective vascular surgery.

Many factors have been suggested for the development of postoperative infection after elective vascular surgery and may be associated with patient characteristics such as blood glucose levels, comorbidities, system characteristics such as preoperative antibiotic usage, intraoperative variables such as use of blood products, and postoperative processes of care such as intensive care unit care.[23-27] Postoperative glucose level appears to be an independent risk factor for infections after infrainguinal vascular surgery.[28] As well, the process of care within the hospital system has been associated with infectious complications.[29] Previous population analysis has also shown a correlation of perioperative infections with the development of later aortic graft infections.[30]

An evaluation of the rates of postoperative infection after elective vascular surgery found the most common infectious complication after vascular surgery was pneumonia. The highest risk procedure associated with infectious complications was open AAA repair. Of significance was the finding that the rates of pneumonia were higher after open AAA than after open thoracic aortic repair. When endovascular aortic procedures were evaluated, TEVAR was associated with more than double the infectious complications compared with EVAR. Reasons for these differences are unclear but demonstrate that TEVAR carries a higher infectious risk even after adjustment for the population. Previous small-center experiences have suggested a significantly increased secondary graft infection rate for TEVAR compared with EVAR.[31] Endarterectomy of head and neck vessels had the lowest rates of infection overall.

The effect of infection on mortality was significant. The risk-adjusted mortality rates for open AAA cases with postoperative infection more than tripled from 2.3% to 7.0% compared with procedures in which infectious complications did not develop. The effect of infection of peripheral bypass was also significant. For peripheral bypass, mortality was almost six times greater in patients with postoperative infectious complications, with UTI being the most common. The occurrence of postoperative complications has been described as the most important factor in determining patient survival after major surgery.[1] These results suggest that there may be substantial opportunities to decrease mortality by reducing UTI complications in the peripheral bypass group.

Patient characteristics were also associated with the development of infection after elective vascular surgery. Postoperative infection was more likely to develop in the aged, even after adjustment of the population. Vemuri et al[32] demonstrated that patient age is independently associated with an increased risk of major postoperative complications after AAA repair. Increased infectious and sepsis rates have been previously reported after all elective surgeries in the aged.[2] This will have major implications, because the aged are the fastest-growing segment of the U.S. population.[33] Focused studies on the aged may offer substantial opportunities when considering the procedure type, the risk of infection, and the effect of infection on mortality, LOS, and cost.

Another significant finding from this analysis was the increased infectious complications in women. This is contrary to previously published data evaluating postoperative infection and gender, in which female gender protected against sepsis and infectious complications.[2] Our data demonstrated that after risk adjustment, infection was more likely to develop in women than men after an elective vascular surgical procedure. Previous work has evaluated the effect of gender and hormone levels on sepsis, suggesting that gender may be involved in the development of sepsis.[34,35] Others have suggested that sex hormones may be significant in shaping the host response.[36,37] The finding that women had higher infectious complications may also help to identify high-risk populations within elective vascular surgical procedures.

Race was also a significant predictor of infectious complications after elective vascular surgery. Previous studies have evaluated outcomes of race and vascular surgery. The likelihood of death after elective AAA repair is significantly greater in black individuals.[38] Reasons for these disparities are multifactorial and may be secondary to access to health care services or biologic differences.[39,40] Race and income have also been shown to have substantial effects on mortality and use of services among Medicare beneficiaries.[41,42]

Hospital characteristics were also associated with the variation of infectious complications after elective vascular surgery. Patients in large hospitals were more likely to experience infectious postoperative complications than those in smaller hospitals. As well, teaching hospitals were more likely associated with postoperative infection after elective vascular surgery. Higher rates of complications at major teaching hospitals have been observed in previous studies using administrative data that showed that patients had significantly higher odds of developing postoperative sepsis.[43] Although the finding of teaching status appears counterintuitive, other authors have evaluated hospital teaching intensity and surgical outcomes. Silber et al[44] reported that survival after surgery is higher at hospitals with higher teaching intensity. Improved survival was found not because of fewer complications but rather lower mortality after complications due to better rescue after complications. Because infections and sepsis are a complication, the finding that infectious complications for elective vascular procedures are greater in teaching institutions is comparable with previous publications. This may be due to hospital case-mix and a number of factors not identifiable through administrative data

We have also demonstrated the effect of infectious complications from a utilization perspective. Cost and LOS were significantly greater when infectious complications develop after elective vascular surgery. LOS varied by procedure, but it was found to vary between a twofold and fourfold increase in LOS when any infectious complication developed. It has been established that factors generating the highest risks for a prolonged LOS were postoperative adverse events.[45] Furthermore, hospital cost tripled with the development of postoperative infection. Others have reported the substantial costs associated with major postoperative complications, and reduction would offer significant cost savings.[3]

The adoption of strategic models may also lead to improved outcomes after elective vascular surgery.[46] These data demonstrate the significant effect on hospital utilization associated with infectious complications, and we have described elective vascular surgery case types, patient characteristics, and hospital characteristics for future study.

This study has several limitations. Administrative data originally were intended primarily for reimbursement, although some reports have validated the use of administrative data for research purposes.[45,47] In addition, the potential for inclusion bias based on limited coding schemes for the many clinical entities cannot be entirely excluded. Because of the large number of hospitals reporting data and the even larger number of coders entering data, accounting for potential coding errors is difficult.

The rates of infection in this study are likely higher than reported due to infections not being appropriately documented in charts and transcribed as infections. Although, according to the Data Quality Reports for the NIS 2005 and 2006 data, an invalid diagnosis code on record was found in 0.03% of all records in 2005 and 0.01% in 2006, and a missing principal diagnosis was found in 0.01%; there were no discrepancies between principal diagnosis and DRG. An invalid ICD-9-CM procedure code on record was found in 0.08% of cases in 2005 and 0.01% in 2006.[6]

Another limitation is that the NIS does not include patients in military hospitals or Veterans Affairs medical centers. The use of smaller cohorts may provide more refined clinical information about infection and infectious complications, although these data are generalizable to the nation and offer insight into national rates of infectious complications after elective vascular surgery.

CONCLUSION

This study has demonstrated the risk for the development of infection after a variety of elective vascular surgical procedures. Among elective vascular surgical procedures, open abdominal aortic surgery had the greatest risk for postoperative infectious complications. Women, octogenarians, and blacks had the highest risk of infectious complications after elective vascular surgery. We have also demonstrated disparities on a systems level, with hospital size and teaching status influencing infectious complications after elective vascular surgery. Hospital infectious complications after elective vascular surgery dramatically increased health care resource utilization. Knowledge of nosocomial complications and delineation of high-risk procedures, patient characteristics, and institution types may offer future targets for cost savings and improved outcomes.

AUTHOR CONTRIBUTIONS

Conception and design: TV
Analysis and interpretation: TV, VD

Data collection: VD
Writing the article: TV, VD
Critical revision of the article: TV, VD, JC, PH, AG
Final approval of the article: TV
Statistical analysis: TV, VD
Obtained funding: TV
Overall responsibility: TV

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DISCUSSION

Dr Peter Gloviczki (*Rochester, Minn*). Your percent rate of infection after open aortic surgery is very high. Does it include ruptured aneurysm and may that be the reason?

Dr Todd R. Vogel. No. Only elective cases were selected. The reality is that the infectious complications are higher than expected as shown from our analysis. These data represent the entire U.S. in a variety of practice settings and are most likely reflective of the community at large. The highest rate of infectious complications after open abdominal aortic surgery was pneumonia.

Another question one may ask is, why are thoracoabdominal infection rates lower than open aneurysm repair? I believe this is likely secondary to center type. Consider the number of centers that are performing thoracoabdominal repairs vs the number of centers performing open AAA [abdominal aortic aneurysm] repairs. Thoracoabdominal repairs are likely performed at high-volume tertiary centers, and this may influence infectious complications. I believe that infectious complications may become surrogate of quality performance in the future as we move forward with pay for performance reimbursement systems.

Dr Jim Dooner (*Victoria, BC, Canada*). I appreciate the data you have brought to us, and they are very helpful going forward with some of the problems that we're confronting. In our hospital, the single most critical issue in post-op management is delirium. In most of the papers I have been hearing, there has been very little mention of it. And when you look at the management of delirium, we have a mania right now for sedating patients, major tranquilizers and so on, and we often see coincident with that a rise in aspiration pneumonias, hypostatic pneumonias, and so on. Could you comment on whether you saw any relationship? But certainly this is a major issue for us: 30% of our post-op open aneurysms have a serious problem with delirium.

Dr Vogel. Unfortunately, I cannot answer this question, as we did not evaluate codes associated with delirium, but I agree that it is a significant problem. Delirium is likely to increase length of stay, which likely increases infectious complications. I think it is an excellent question; I am just unable to answer it from the data presented.

Dr Natalia Egorova (*New York, NY*). I have years of experience working with large health care data sets, and I also work with NIS [National Inpatient Sample]. I understand how it can be challenging to correctly identify complications and outcomes using ICD-9 codes [International Classification of Diseases, 9th edition]. NIS doesn't have a "present on admission" flag. How do you separate patients admitted with infections from patients who develop infections (complications) in the hospital?

Dr Vogel. We excluded cases with an infection ICD-9 code contained in the principal diagnosis and all ICD-9 diagnosis or procedures codes for immunocompromised states in any diagnosis or procedure position. This methodology is recommended by the AHRQ [Agency for Healthcare Research and Quality] Patient Safety Indicator (PSI) No. 13 "Postoperative Sepsis" to identify the problems that patients experience as a result of exposure to the health care system.

To define the infection, there are specific ICD-9 codes for wound infection, UTI [urinary tract infection], and pneumonia. Furthermore, all these patients were elective admissions for vascular procedures, and these codes are very unlikely to have been present on admission.

Dr Egorova. The second question is about cost. Do you present data about charges or cost? Were the data adjusted for inflation?

Dr Vogel. To transform hospital charges in the data to cost data, we utilized the HCUP [Healthcare Cost and Utilization Project] Cost-to-Charge ratio files. The HCUP Cost-to-Charge Ratio Files are hospital-level files designed to supplement the data elements in the NIS database. All costs were then adjusted to the first year of the study.

Dr Egorova. And the last one is about propensity analysis. Over here, you said that you saw the cases with a high rate of infection. At what stage of analysis was the propensity scoring used?

Dr Vogel. Risk-adjusted rates of postoperative infection for each procedure were calculated by using a logistic regression model created with infection as the dependent variable. The mean predicted probability of outcome was then calculated for each procedure, and the expected rate as a percentage was generated. This methodology has been previously reported in epidemiological studies to calculate case-mix adjusted rates.

Dr Egorova. Did you use Elixhauser codes or propensity score matching in the analysis? Thank you.

Dr Vogel. We utilized Elixhauser comorbidities when calculating the predicted probability score.

Dr Ahsan Ali (*Little Rock, Ark*). In these kind of vague data sets, you have to take the information with some caution because the diagnosis of pneumonia is vague. Most of the time when a patient is having respiratory issues, residents say they may be having pneumonia. They may be having congestive heart failure for all we know. So that is one point.

Secondly, if you could clarify, did the patients that had an infection stay longer than 4 days? Were they included? So were there carotids that stayed that long? I'm not sure what your criteria for inclusion were. Also, same-day procedures were not included?

Dr Vogel. The study is limited by the data that are collected at the hospital level, and this is dependent upon the coders and the hospital entry. There may be variability; however, I would suggest that infectious complications are likely undercoded or not entirely captured in the data set. Therefore, I believe these estimates may actually be low compared to a prospective data set designed to evaluate infection.

As well, all patients were included in the study that were admitted undergoing elective vascular procedures. The AHRQ recommends using 4 days as a cutoff, but this was not utilized in this analysis.

Dr Ali. So there were quite a few fem-distal or fem-pop bypass patients that may have gone home before 4 days who did not get infected. Doesn't it change the denominator for all vascular procedures?

Dr Vogel. Four days is a suggested cutoff by the AHRQ for infectious complications, but this was not utilized for this analysis. All elective bypass procedures were evaluated, regardless of LOS [length of stay].

Dr Ronald Fairman (*Philadelphia, Pa*). I may have missed this, but did your analysis include readmissions, meaning a patient had a fem-pop, went home, and readmitted with infection?

Dr Vogel. No. All infectious complications evaluated occurred during the index admission. The NIS data set does not allow for longitudinal analysis.

Dr Fairman. So if not then, perhaps this analysis may underestimate the incidence of infection.

Dr Vogel. Yes. The infectious complications would most certainly be higher than we report if readmissions were included in the analysis. As well, believe that the current hospital coding most likely underestimates infectious complications and is a limitation of the NIS data set.