# The Risk of Major Elective Vascular Surgical Procedures in Patients With End-Stage Renal Disease

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**Objective:** To examine the postoperative complications and death rate of major elective vascular surgery procedures in patients with end-stage renal disease (ESRD).

**Background Data:** Patients with ESRD undergoing elective major vascular surgical procedures are thought to have a high rate of postoperative complications and death.

**Methods:** The American College of Surgeons-National Surgical Quality Improvement Program database was used to select ESRD and non-ESRD patients who had elective major vascular surgical procedures between 2004 and 2008. Multivariable logistic regression analysis was used to examine the impact of ESRD on 30-day surgical outcomes adjusted for age, race, sex, work relative value units, American Society of Anesthesiology class, and recent operations (within the past 30 days).

**Results:** ESRD patients undergoing elective major vascular surgery were significantly more likely than non-ESRD patients to develop surgical site infection, unplanned intubation, ventilator dependence, combined pulmonary outcome, and a need for reoperation within 30 days of surgery. Importantly, ESRD patients undergoing elective major vascular surgery were also at higher risk for composite outcome and death within 30 days from surgery. ESRD patients above age 65 years undergoing elective major vascular surgery had far worse 30-day outcomes when compared with the younger ESRD cohort. Examining these data by their anatomic site (carotid, aortic, and peripheral) demonstrated elevated rates of postoperative complications and death in patients with ESRD undergoing open abdominal aortic aneurysm repair, carotid endarterectomies, and peripheral vascular operations compared with the non-ESRD cohort. Endovascular abdominal aortic aneurysm repair in ESRD patients had complications and death rates comparable with non-ESRD patients.

**Conclusions:** Patients with ESRD undergoing elective vascular surgery have a significantly elevated risk of postoperative complications and death after major vascular surgical operations—particularly in patients over age 65. These data, in combination with well-established reduced survival for the older ESRD population, call into question the utility of most carotid and aortic operations in these patients in the absence of symptoms or a rapidly enlarging aneurysm.

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Elective vascular surgery is markedly different than most other surgical specialties as much of the operative care is for asymptomatic conditions—abdominal aortic aneurysm and carotid artery occlusive disease.[1–4] The justification for operative intervention in these conditions has been well documented in a number of randomized trials.[1,2,4] In general, the patients suffer a modest initial mortality/morbidity risk with the procedure, and over time, gain a benefit by a reduction in adverse events in the long term. In order for any benefit to accrue, vascular patients undergoing procedures for these asymptomatic conditions must have modest longevity. As such, patients considered for enrollment in the above pivotal trials were highly selected.

Patients with end-stage renal disease (ESRD) treated with chronic dialysis are increasingly undergoing surgical procedures, especially in patients over age 65.[5–7] Older patients with ESRD once beyond 65 years have a mean life expectancy of less than 5 years.[8] Withdrawal of dialysis becomes one of the most common causes of death.[9] Given this, it would seem unlikely that many vascular patients with ESRD would gain significant benefit from surgical care of asymptomatic conditions in the above situations based on longevity alone.

Another very important variable in the risk benefit of surgical treatment in asymptomatic conditions is perioperative morbidity/mortality. In the models used to justify vascular care in abdominal aortic aneurysm and carotid artery occlusive disease, modest increases in these events will negate any long-term benefits.

With the increasing incidence and prevalence of ESRD has come a presumed increase in critical limb ischemia as diabetes (a major risk factor for both) has also been on the rise. Unlike most abdominal aortic aneurysm and carotid artery occlusive disease, critical limb ischemia is symptomatic without a reasonable alternative strategy.

Although selected series of revascularization in ESRD have demonstrated modest limb salvage rates, this finding has not been uniformly reported and the interpretation regarding the value of revascularization in ESRD has also been debated.[6,7] The mortality associated with revascularization in ESRD populations has consistently been markedly higher than non-ESRD patients, both perioperative and near term. The alternative for this population is equally dismal as large registries have demonstrated significant perioperative and near-term mortality from primary and secondary major amputation.[10]

Using the large American College of Surgeons-National Surgical Quality Improvement Program database, we examined the postoperative morbidity and mortality in vascular patients undergoing major elective operations for abdominal aortic aneurysm, carotid

artery occlusive disease, and peripheral disease with and without ESRD. The findings of that analysis form the basis of this report.

## PATIENTS AND METHODS

### Data Source

Data for this study were obtained from the American College of Surgeons National Surgical Quality Improvement Program, which assesses preoperative risk factors, operative data, and 30-day postoperative outcomes for sampled patients undergoing major surgery at participating hospitals. A trained surgical clinical nurse collects the data from the patient's medical records. All data contained within the dataset are deidentified. On the 30th postoperative day, the nurse obtains outcome information through chart review, reports from morbidity and mortality conferences, and communication with each patient or the patient's family by letter or by telephone.[11]

### Patients

The American College of Surgeons National Surgical Quality Improvement Program database was used to select patients who had major elective vascular surgical operations between 2005 and 2008. As emergent surgical operations are known to have an elevated risk of complications and death, all cases coded as "emergent case" in the dataset were excluded. Other exclusions included operations aimed at creating or revising hemodialysis access. No patients with major or minor amputations coded as a principal procedure were included in this analysis. Procedures that were performed with a frequency of less than 5 cases were excluded from the analysis. Additionally, patients with missing information for sex, race, wound classification, age, work relative value units, and whether or not the patient had an operation within the past 30 days were also excluded. Further subgroup analysis of elective vascular cases divided them into 3 separate categories based on anatomical considerations (carotid, aortic, and peripheral), assuming the indications and also postoperative complications would be different between groups. Common procedure terminology code groupings used for the analysis are listed in Table 1.

The "currently on dialysis" variable was used to categorize patients into ESRD and non-ESRD groups. This variable is defined as: "yes" "if the patient has renal failure requiring treatment with peritoneal dialysis, hemodialysis, hemofiltration, hemodiafiltration, or ultrafiltration within 2 weeks before surgery" according to the American College of Surgeons National Surgical Quality Improvement Program data user guide. As all operations collected were elective, the assumption is that none of the patients in the analysis had acute renal failure. Finally, patients were also grouped according to age: $\geq$65 years versus <65 years (where <65 years is the reference group), as this is a threshold age where the reported mean survival is below 5 years in the United States Renal Data Service.

### Definitions of Outcomes of Interest

Postoperative outcomes of interest were complications occurring within 30 days of the index operation, return to the operating room within 30 days, postsurgical length of stay, and 30-day mortality. Postoperative complications included surgical site infection (including superficial and deep-wound infections); cardiovascular, pulmonary, urinary tract, and central nervous system complications; return to the operating room; and postoperative hospital length of stay. In addition, we also grouped complications to form a composite pulmonary outcome (pneumonia, failure to wean from ventilator for more than 48 hours, or reintubation for cardiorespiratory failure). The following complications were grouped together and called vascular complications: stroke/cerebrovascular accident and myocardial infarction. An overall composite outcome was created by combining surgical site infection and vascular and pulmonary complications.

### Statistical Analyses

Baseline patient characteristics were compared among the ESRD groups (yes or no) using $\chi^2$ tests of association for categorical variables and the unpaired $t$ test for continuous variables. Unadjusted postoperative outcome rates were compared by dialysis status using the Pearson $\chi^2$ test of association.

For each of the dichotomous postoperative outcomes, the adjusted odds ratio for the ESRD group was compared with that of the non-ESRD group using multilevel multivariable logistic regression analysis. All regression analyses were adjusted for age, sex, race/ethnicity, work relative value units, Anesthesia Society of America class, type of anesthesia (general vs nongeneral), and an operation within the past 30 days. Surgical site infection was additionally adjusted for wound classification. Reported odds ratios represent the ratio of the odds of a postoperative outcome in the ESRD group to that of the non-ESRD group as the reference group. A confidence interval that includes 1 implies no statistically significant difference in the odds of a given outcome between groups. All analyses were performed using SAS software, version 9.3 (SAS Institute Inc., Cary, NC).

## RESULTS

Thirty-six thousand two hundred and twenty-two patients who underwent elective major vascular operations from 2005 to 2008 were identified in the American College of Surgeons National Surgical Quality Improvement Program dataset. The subgroup with ESRD included 1409 patients (3.9% of the total). Sixty-five percent were male and 35% were female. The majority were white (82%), followed by African Americans (7%) and unknown race (7%). The remainder was Asians, Hispanics, and Native Americans. The mean age of all the patients was 70 years, with a range of 16 to 90 years.

Preoperative risk factors for patients in the ESRD group are presented in Table 2. The ESRD group undergoing elective vascular surgery had more comorbid conditions compared with non-ESRD patients. Most striking was a markedly increased rate of diabetes, past revascularization/amputation, gangrene, past operation within 30 days, and reduced functional status. Surgical cases in the ESRD group had longer operative times and also were more likely involved a potentially infected field—consistent with the high incidence of gangrene in the peripheral cases for the population.

The incidence of postoperative adverse events is presented in Table 3. ESRD patients undergoing elective vascular operations had a markedly greater rate of 30-day overall complications (composite outcome: 16.5% vs 8.4%; $P < 0.001$), death (7.2% vs 1.4%; $P < 0.001$), and return to the operating room (23.8% vs 8.5%; $P < 0.001$) compared with the non-ESRD cohort. Most of the increase in complications was driven by increased rates of pulmonary complications and surgical site infections. Additionally, the average length of postoperative surgical stay was twice as long for ESRD patients.

Odds ratios of postoperative events adjusted for race, sex, age, relative value units, American Society of Anesthesiology class, type of anesthesia, and past operation within 30 days are presented in Table 4. Patients with ESRD undergoing elective major vascular surgery were significantly more likely to develop surgical site infection, unplanned intubation, ventilator dependence, and a return to the operating room within 30 days as compared with non-ESRD patients. In addition, ESRD patients were more likely to develop a combined pulmonary outcome, composite outcome, and death within 30 days from surgery.

Further stratification of the 1409 ESRD patients based on age [64 years or less n = 682 (48%), and 65 years or greater n = 727

**TABLE 1.** Vascular Common Procedure Terminology Codes Used for Patient Selection

| | |
|---|---|
| All vascular common procedure terminology codes | 34800, 34802–34806, 34808, 34812, 34813, 34820, 34825, 34826, 34830–34834, 34900, 35001, 35002, 35005, 35011, 35013, 35021, 35022, 35045, 35081, 35091, 35102, 35111, 35112, 35121, 35122, 35131, 35141, 35151, 35188, 35201, 35206, 35207, 35211, 35216, 35221, 35226, 35236, 35241, 35246, 35251, 35256, 35261 35266, 35271, 35276, 35281, 35286, 35301–35306, 35311, 35321, 35331, 35341, 35351, 35355, 35361, 35363 , 35371, 35372, 35390, 35480–35485, 35500, 35501, 35506, 35508–35512, 35515, 35516, 35518, 35521–35523, 35525, 35526, 35531, 35533, 35535–35540, 35548, 35549, 35551, 35556, 35558, 35560, 35563, 35565, 35566, 35570–35572, 35583, 35585, 35587, 35600, 35681–35683, 35685, 35686, 35691, 35693–35695, 35697, 35700, 35701, 35721, 35741, 35761, 35860, 35870, 35875, 35876, 35879, 35881, 35883, 35884, 35901, 35903, 35905, 35907, 37140, 37145, 37160, 37180, 37181–37183 |
| Peripheral | 34813, 35011, 35013, 35045, 35142, 35151, 35152, 35206, 35226, 35236, 35256, 35266, 35286, 35302–35305, 35321, 35351, 35355, 35371, 35372, 35516, 35521, 35523, 35525, 35538, 35551, 35556, 35558, 35565, 35566, 35571, 35583, 35585, 35587, 35666, 35700, 35721, 35741, 35860, 35879, 35881, 35883, 35884, 35903 |
| Carotid | 35301, 35390 |
| Aortic: | |
| Endovascular | 34802, 34803, 34800, 34805, 34831, 34808, 34833 |
| Open | 35081, 35102, 35091, 35141, 35540, 34830, 34820, 34832, 34834 |

(52%)] was performed. Older ESRD patients undergoing elective vascular surgery were more likely to have unplanned intubation (odds ratio: 1.84; 95% confidence interval: 1.07–3.16), worse combined pulmonary outcome (odds ratio: 1.61; 95% confidence interval: 1.08–2.41), and postoperative death (odds ratio: 1.75; 95% confidence interval: 1.12–2.73), compared with younger ESRD patients.

Patients undergoing major elective vascular surgery were further subdivided into the following 3 anatomical groups, "aortic," "carotid," and "peripheral," and evaluated for the effect of ESRD on postoperative outcomes. The "aortic" group was further narrowed to surgery performed for abdominal aortic aneurysm only (total n = 8423; ESRD n = 109, 1.3%) (Table 5). In adjusted analysis, the rate of stroke/cerebrovascular accident with neurological deficit (odds ratio: 4.46; 95% confidence interval: 1.30–15.30), combined vascular outcome (odds ratio: 3.62; 95% confidence interval: 1.26–10.38), and death within 30 days of the operation (odds ratio 4.15; 95% confidence interval: 1.98–8.71) continued to be significantly elevated in patients with ESRD undergoing elective abdominal aortic aneurysm repair. Further breakdown of patients with abdominal aortic aneurysm repair into open (n = 3417) and endovascular (n = 5006) groups found that rates of unplanned intubations (odds ratio: 3.58; 95% confidence interval: 1.42–9.03), return to the operating room (odds ratio: 3.06; 95% confidence interval: 1.43–6.53), combined vascular outcome (odds ratio: 4.68; 95% confidence interval: 3.09–21.42), and death within 30 days of operation (odds ratio: 7.86; 95% confidence interval: 3.09–19.97) were significantly elevated for patients with ESRD in the open group, whereas stroke/cerebrovascular accident with neurological deficit (odds ratio: 4.70; 95% confidence interval: 1.01–21.93) was the only complication with significant elevation in the ESRD group undergoing endovascular abdominal aortic aneurysm repair. After adjustment for the type of anesthesia, unplanned intubations (odds ratio: 3.66; 95 % confidence interval: 1.45–9.22), reoperations (odds ratio: 3.12; 95% confidence interval: 1.46–6.66), and 30-day mortality (odds ratio: 7.84; 95% confidence interval: 3.08–19.96) continued to be significantly elevated for ESRD patients undergoing open abdominal aortic aneurysm repair, but no postoperative adverse outcome remained significantly different between ESRD and non-ESRD patients undergoing endovascular abdominal aortic aneurysm repair.

There were 15,386 patients in the "carotid" group, of which 146 (1%) had ESRD at the time of their operation. The rate of death within 30 days of the operation was the only postoperative variable significantly elevated in the ESRD group (odds ratio: 3.52; 95% confidence interval: 1.48–8.40) (Table 5). We attempted to look at the postoperative stroke rate after carotid operations and compare stroke rates for patients on and off dialysis; however, the number of adverse events was too low in both groups to draw any meaningful conclusions. We also examined possible indications for carotid endarterectomies in our patients. We used a history of transient ischemic attack and cerebrovascular accident with and without neurological deficit as surrogate markers for "symptomatic conditions." We found that 49% of ESRD patients undergoing a carotid endarterectomy for carotid stenosis had a history of transient ischemic attacks or a cerebrovascular accident with or without neurological deficits, compared with 44% in the non-ESRD group. The confidence intervals for odds ratios in Table 5 for aortic and carotid disease are fairly wide due to the low number of events.

The "peripheral" group had 10,361 patients, of which 1099 (11%) had ESRD at the time of their operation—by far the greatest total number and percentage of ESRD patients in our 3 anatomical groups. These ESRD patients were significantly more likely to require unplanned intubation (odds ratio: 2.38; 95% confidence interval: 1.66–3.41), a return to the operating room (odds ratio: 1.53; 95% confidence interval: 1.30–1.80), and suffer combined pulmonary outcome (odds ratio: 1.91; 95% confidence interval: 1.45–2.52), composite outcome (odds ratio: 1.30; 95% confidence interval: 1.08–1.57), and die (odds ratio: 3.66; 95% confidence interval: 2.67–5.03) after elective peripheral vascular operations compared with the non-ESRD cohort. (Table 5)

The "peripheral" group was further broken down into 2 subgroups based on the presence or absence of rest pain/gangrene preoperatively. This stratification separated claudicants from patients with critical limb ischemia. This resulted in only 2 minor differences in the outcome variables examined. The composite outcome for patients on dialysis with critical limb ischemia remained significantly elevated (odds ratio: 1.52; 95% confidence interval: 1.18–1.95), but became nonsignificant for patients on dialysis with claudication only (odds ratio: 1.13; 95% confidence interval: 0.85–1.50) when directly compared with the nondialyzed peripherial cohort (Table 5). The venous thromboembolism outcome was nonsignificant for patients with critical limb ischemia (odds ratio: 1.12; 95% confidence interval: 0.45–2.76), but was significant for patients with claudication only (odds ratio: 2.02; 95% confidence interval: 1.02–4.01).

The 30-day postoperative mortality rates were further examined in patients on dialysis with and without critical limb ischemia. In the multivariate analysis, both groups were found to have a significantly elevated risk of dying within 30 days from the index operation (odds ratio: 4.49; 95% confidence interval: 2.98–6.76 and odds ratio:

 

**TABLE 2.** Patient Characteristics by Dialysis Status in Patients Having Undergone Vascular Procedures

| | | Total (n = 36,222, 100%) | | Not on Dialysis (n = 34,813, 96.1%) | | On Dialysis (n = 1409, 3.9%) | | |
|---|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % | *P* |
| Patient demographics | | | | | | | | |
| Sex | Male | 23,686 | 65.4% | 22,875 | 65.7% | 811 | 57.6% | <0.001 |
| | Female | 12,536 | 34.6% | 11,938 | 34.3% | 598 | 42.4% | |
| Race | White, not of Hispanic origin | 29,562 | 81.6% | 28,842 | 82.8% | 720 | 51.1% | <0.001 |
| | Hispanic, white | 524 | 1.5% | 473 | 1.4% | 51 | 3.6% | |
| | Hispanic, black | 13 | 0.0% | 11 | 0.0% | 2 | 0.1% | |
| | Black, not of Hispanic origin | 2601 | 7.2% | 2122 | 6.1% | 479 | 34.0% | |
| | American Indian or Alaska Native | 99 | 0.3% | 94 | 0.3% | 5 | 0.4% | |
| | Asian or Pacific Islander | 378 | 1.0% | 350 | 1.0% | 28 | 2.0% | |
| | Hispanic, color unknown | 573 | 1.6% | 515 | 1.5% | 58 | 4.1% | |
| | Unknown | 2472 | 6.8% | 2406 | 6.9% | 66 | 4.7% | |
| Age (years, truncated at 90), mean (standard deviation) | | 70.1 (11.0) | | 70.3 (10.8) | | 64.0 (13.8) | | <0.001 |
| Preoperative status | | | | | | | | |
| Diabetes | | 9755 | 26.9% | 9029 | 25.9% | 726 | 51.5% | <0.001 |
| Congestive heart failure within 30 days before surgery | | 580 | 1.6% | 476 | 1.4% | 104 | 7.4% | <0.001 |
| History of severe chronic obstructive pulmonary disease | | 4805 | 13.3% | 4644 | 13.3% | 161 | 11.4% | 0.038 |
| Open wound/wound infection | | 3814 | 10.5% | 3222 | 9.3% | 592 | 42.0% | <0.001 |
| More than10% loss body weight in last 6 months | | 494 | 1.4% | 453 | 1.3% | 41 | 2.9% | <0.001 |
| Functional health status before surgery | Independent | 33,116 | 91.4% | 32,089 | 92.2% | 1027 | 72.9% | <0.001 |
| | Partially dependent | 2739 | 7.6% | 2415 | 6.9% | 324 | 23.0% | |
| | Totally dependent | 367 | 1.0% | 309 | 0.9% | 58 | 4.1% | |
| History of myocardial infarction 6 months before surgery | | 641 | 1.8% | 583 | 1.7% | 58 | 4.1% | <0.001 |
| Previous percutaneous coronary intervention | | 6823 | 18.8% | 6546 | 18.8% | 277 | 19.7% | 0.42 |
| Previous cardiac surgery | | 8420 | 23.2% | 8057 | 23.1% | 363 | 25.8% | 0.022 |
| History of angina 1 month before surgery | | 906 | 2.5% | 857 | 2.5% | 49 | 3.5% | 0.017 |
| Hypertension requiring medication | | 29,946 | 82.7% | 28,688 | 82.4% | 1258 | 89.3% | <0.001 |
| History of revascularization/amputation | | 7844 | 21.7% | 7358 | 21.1% | 486 | 34.5% | <0.001 |
| Rest pain/gangrene | | 4530 | 12.5% | 4118 | 11.8% | 412 | 29.2% | <0.001 |
| History of transient ischemic attacks | | 5759 | 15.9% | 5642 | 16.2% | 117 | 8.3% | <0.001 |
| Cerebrovascular accident/stroke with neurological deficit | | 3559 | 9.8% | 3416 | 9.8% | 143 | 10.1% | 0.677 |
| Cerebrovascular accident/stroke with no neurological deficit | | 2577 | 7.1% | 2443 | 7.0% | 134 | 9.5% | <0.001 |
| Past operation within 30 days | | 1286 | 3.6% | 1101 | 3.2% | 185 | 13.1% | <0.001 |
| Preoperative BUN, mean (standard deviation) | | 20.6 (11.3) | | 19.8 (10.2) | | 38.3 (18.7) | | <0.001 |
| Preoperative serum creatinine, mean (standard deviation) | | 1.3 (1.2) | | 1.1 (0.6) | | 6.1 (2.7) | | <0.001 |

(*Continued*)

**TABLE 2.** (*Continued*)

| | | Total (n = 36,222, 100%) | | Not on Dialysis (n = 34,813, 96.1%) | | On Dialysis (n = 1409, 3.9%) | | |
|---|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % | *P* |
| Surgical profile | | | | | | | | |
| Wound classification | Clean | 33,903 | 93.6% | 33,054 | 94.9% | 849 | 60.3% | <0.001 |
| | Clean/contaminated | 568 | 1.6% | 524 | 1.5% | 44 | 3.1% | |
| | Contaminated | 589 | 1.6% | 516 | 1.5% | 73 | 5.2% | |
| | Dirty/infected | 1162 | 3.2% | 719 | 2.1% | 443 | 31.4% | |
| ASA classification | Missing | 27 | 0.0% | 27 | 0.0% | | | <0.001 |
| | No disturbance | 92 | 0.3% | 90 | 0.3% | 2 | 0.1% | |
| | Mild disturbance | 3171 | 8.8% | 3154 | 9.1% | 17 | 1.2% | |
| | Severe disturbance | 26,949 | 74.5% | 26,202 | 75.3% | 747 | 53.0% | |
| | Life threat | 5961 | 16.5% | 5320 | 15.3% | 641 | 45.5% | |
| | Moribund | 22 | 0.1% | 20 | 0.1% | 2 | 0.1% | |
| Year of operation | 2006 | 4,669 | 12.9% | 4512 | 13.0% | 157 | 11.1% | 0.024 |
| | 2007 | 14,265 | 39.4% | 13,667 | 39.3% | 598 | 42.4% | |
| | 2008 | 17,288 | 47.7% | 16,634 | 47.8% | 654 | 46.4% | |
| Type of anesthesia | General | 31,009 | 85.6% | 29,861 | 85.8% | 1148 | 81.5% | <0.001 |
| | Not general | 5213 | 14.4% | 4952 | 14.2% | 261 | 18.5% | |
| Work relative value unit, mean (standard deviation) | | 22.2 (6.2) | | 22.3 (6.1) | | 19.3 (8.3) | | <0.001 |
| Total operation time (minutes), mean (standard deviation) | | 162.6 (93.3) | | 162.4 (92.5) | | 167.2 (111.9) | | <0.001 |

BUN indicates blood urea nitrogen; ASA, American Society of Anesthesiology.

**TABLE 3.** Postoperative Outcomes in ESRD Patients Having Undergone Vascular Procedures

| | Total (n = 36,222, 100%) | | Not on Dialysis (n = 34,813, 96.1%) | | On Dialysis (n = 1409, 3.9%) | | |
|---|---|---|---|---|---|---|---|
| **Postoperative Outcome** | n | % | n | % | n | % | *P* |
| Surgical site infection | 1,466 | 4.0% | 1,353 | 3.9% | 113 | 8.0% | <0.001 |
| Pulmonary embolism or DVT/thrombophlebitis | 299 | 0.8% | 275 | 0.8% | 24 | 1.7% | <0.001 |
| Pneumonia | 691 | 1.9% | 652 | 1.9% | 39 | 2.8% | 0.016 |
| Unplanned intubation | 754 | 2.1% | 687 | 2.0% | 67 | 4.8% | <0.001 |
| Failure to wean | 809 | 2.2% | 746 | 2.1% | 63 | 4.5% | <0.001 |
| Urinary tract infection | 544 | 1.5% | 529 | 1.5% | 15 | 1.1% | 0.169 |
| Stroke/cerebrovascular accident with neurological deficit | 365 | 1.0% | 350 | 1.0% | 15 | 1.1% | 0.827 |
| Myocardial infarction | 153 | 0.4% | 144 | 0.4% | 9 | 0.6% | 0.201 |
| Return to operating room | 3,310 | 9.1% | 2,975 | 8.5% | 335 | 23.8% | <0.001 |
| Pulmonary outcome | 1,488 | 4.1% | 1,367 | 3.9% | 121 | 8.6% | <0.001 |
| Vascular outcome | 509 | 1.4% | 486 | 1.4% | 23 | 1.6% | 0.460 |
| Composite outcome | 3,170 | 8.8% | 2,938 | 8.4% | 232 | 16.5% | <0.001 |
| Death within 30 days of operation | 603 | 1.7% | 502 | 1.4% | 101 | 7.2% | <0.001 |
| Length of postoperative surgical stay in days, mean (standard deviation) | 4.2 (6.5) | | 4.0 (6.2) | | 8.0 (11.0) | | <0.001 |
| Excluding those with 30-day mortality, mean (standard deviation) | 4.1 (6.5) | | 3.9 (6.2) | | 8.0 (11.3) | | <0.001 |

For patients with 30-day mortality (n = 603), it is unknown whether death occurred before hospital discharge.
DVT indicates deep-vein thrombosis.

2.70; 95% confidence interval: 1.61–4.57) when compared with the non-ESRD peripherial cohort. When the exact mortality rates were further analyzed, ESRD patients with critical limb ischemia had the highest 30-day postoperative mortality (10.8%), followed by ESRD patients without critical limb ischemia (5.3%), non-ESRD patients with critical limb ischemia (2.4%), and non-ESRD patients without critical limb ischemia (1.2%) ($P < 0.001$).

## DISCUSSION

To our knowledge, this report is the largest study examining postoperative adverse events and death in patients with ESRD after elective major vascular surgical procedures. Most of the findings were expected—ESRD patients undergoing elective major vascular surgery have a higher prevalence of preoperative risk factors for complications and death. This translated into a significantly higher rate of

 

**TABLE 4.** Unadjusted and Adjusted Odds Ratios of Postoperative Outcomes for ESRD Patients Having Undergone Vascular Surgeries (N = 1409)

| Postoperative Outcome | Unadjusted Odds Ratio (95% CI) | Adjusted Odds Ratio* (95% CI) |
|---|---|---|
| Surgical site infection | 2.16 (1.77–2.63) | 1.54 (1.22–1.93) |
| Pulmonary embolism or DVT/thrombophlebitis | 2.18 (1.43–3.31) | 1.46 (0.92–2.32) |
| Pneumonia | 1.49 (1.07–2.07) | 1.41 (0.99–1.99) |
| Unplanned intubation | 2.48 (1.92–3.21) | 2.07 (1.56–2.74) |
| Failure to wean | 2.14 (1.64–2.78) | 1.61 (1.21–2.14) |
| Urinary tract infection | 0.70 (0.42–1.17) | 0.59 (0.34–1.00) |
| Stroke/cerebrovascular accident with neurological deficit | 1.06 (0.63–1.78) | 0.77 (0.44–1.33) |
| Myocardial infarction | 1.55 (0.79–3.04) | 1.50 (0.74–3.05) |
| Return to operating room | 3.34 (2.94–3.80) | 2.11 (1.83–2.44) |
| Pulmonary outcome | 2.30 (1.89–2.79) | 1.96 (1.58–2.42) |
| Vascular outcome | 1.17 (0.77–1.79) | 0.98 (0.63–1.53) |
| Composite outcome | 2.14 (1.85–2.47) | 1.56 (1.32–1.83) |
| Death within 30 days of operation | 5.28 (4.23–6.58) | 4.46 (3.48–5.72) |

Odds ratios are presented in relation to patients not currently on dialysis.
CI indicates confidence interval; DVT, deep-vein thrombosis.
*Adjusted for fixed effects of race, sex, age, work relative value units, American Society of Anesthesiology classification, type of anesthesia, and whether or not the patient had undergone an operation within the past 30 days. Surgical site infection additionally adjusted for wound classification.

**TABLE 5.** Adjusted Odds Ratios (95% Confidence Interval) of Postoperative Outcomes for ESRD Patients on Dialysis Having Undergone Aortic, Carotid, or Peripheral Procedures

| | Type of Procedure | | | | |
|---|---|---|---|---|---|
| | Aortic (n = 8423) | Carotid (n = 15,386) | Peripheral (n = 10,361) | | |
| Postoperative Outcome | Currently on Dialysis (n = 109) | Currently on Dialysis (n = 146) | Currently on Dialysis (n = 1099) | Currently on Dialysis, Presence of Rest Pain/Gangrene (n = 416) | Currently on Dialysis, No Presence of Rest Pain/Gangrene (n = 683) |
| Surgical site infection | 1.73 (0.78–3.84) | 0.00 (0.00–0.00) | 1.11 (0.88–1.40) | 1.24 (0.91–1.69) | 1.02 (0.71–1.45) |
| Pulmonary embolism or DVT/thrombophlebitis | 0.00 (0.00–0.00) | 0.00 (0.00–0.00) | 1.58 (0.94–2.67) | 1.12 (0.45–2.76) | 2.02 (1.02–4.01) |
| Pneumonia | 0.77 (0.23–2.54) | 1.68 (0.60–4.70) | 1.53 (0.99–2.38) | 1.54 (0.84–2.83) | 1.47 (0.75–2.89) |
| Unplanned intubation | 2.18 (0.97–4.88) | 1.13 (0.40–3.18) | 2.38 (1.66–3.41) | 2.70 (1.69–4.31) | 2.19 (1.24–3.88) |
| Failure to wean | 1.74 (0.80–3.78) | 1.88 (0.73–4.82) | 1.44 (0.97–2.14) | 1.69 (0.98–2.90) | 1.22 (0.67–2.22) |
| Urinary tract infection | 0.70 (0.17–2.89) | 1.21 (0.29–5.06) | 0.50 (0.27–0.91) | 0.37 (0.15–0.94) | 0.71 (0.32–1.61) |
| Stroke/cerebrovascular accident with neurological deficit | 4.46 (1.30–15.30) | 0.95 (0.30–3.03) | 0.81 (0.34–1.92) | 0.74 (0.21–2.54) | 0.93 (0.27–3.24) |
| Myocardial infarction | 2.12 (0.28–16.08) | 1.26 (0.17–9.43) | 1.33 (0.57–3.07) | 1.93 (0.69–5.39) | 0.77 (0.17–3.50) |
| Return to operating room | 1.77 (0.95–3.30) | 1.52 (0.89–2.60) | 1.53 (1.30–1.80) | 1.68 (1.33–2.11) | 1.47 (1.16–1.87) |
| Pulmonary complication | 1.58 (0.81–3.09) | 1.93 (0.98–3.79) | 1.91 (1.45–2.52) | 2.19 (1.51–3.17) | 1.66 (1.09–2.53) |
| Vascular complication | 3.62 (1.26–10.38) | 1.05 (0.38–2.89) | 1.01 (0.54–1.88) | 1.23 (0.56–2.69) | 0.81 (0.29–2.23) |
| Surgical site infection, pulmonary, or vascular complication | 1.61 (0.93–2.78) | 1.53 (0.85–2.75) | 1.30 (1.08–1.57) | 1.52 (1.18–1.95) | 1.13 (0.85–1.50) |
| Death within 30 days of operation | 4.15 (1.98–8.71) | 3.52 (1.48–8.40) | 3.66 (2.67–5.03) | 4.49 (2.98–6.76) | 2.70 (1.61–4.51) |

Odds ratios are adjusted for fixed effects of race, sex, age, work relative value units, American Society of Anesthesiology classification, type of anesthesia, and whether or not the patient had undergone an operation within the past 30 days. Surgical site infection was additionally adjusted for wound classification.
Odds ratios are presented in relation to patients not currently on dialysis by procedure.
CI indicates confidence interval; DVT, deep-vein thrombosis.

postoperative surgical site infection, unplanned intubation, ventilator dependence, return to the operating room, composite pulmonary outcome, composite outcome, and 30-day mortality for ESRD patients after elective surgery compared with non-ESRD patients. Indeed, the death rate in ESRD patients after elective vascular surgery was increased 4-fold for all operations in the adjusted analysis. Advanced age in ESRD further increased the risk of unplanned intubations, composite pulmonary outcome, and 30-day mortality. When we examined the effect of ESRD on postoperative outcomes by anatomical sites, open aortic operations carried the highest risk of complications and death, followed by peripheral revascularizations and then carotid revascularization, which is likely true for non-ESRD patients, but the magnitude in ESRD patients is certainly higher. Despite select reports from single centers arguing that elective major vascular operations can be done on ESRD patients with modest increased risk,[5,12,13] when examining data from large multicenter databases, the results are substantially more sobering.

These findings argue for a more rational approach when considering major elective vascular surgical interventions for ESRD patients. Although many elective vascular operations for ESRD are

 

being performed for symptomatic peripheral conditions,[6,7] the effectiveness of carotid revascularization or aortic revascularization for asymptomatic disease is highly questionable, given these data. This is especially true for older ESRD patients, as mortality data from the US renal database show a life expectancy of less than 5 years for patients over the age of 65 on dialysis. Given the markedly increased postoperative complications and death in these patients after elective carotid and aortic revascularization, the need for a different risk-benefit analysis than that published in the randomized trials would seem appropriate. Perhaps, elderly ESRD patients should not undergo abdominal aortic aneurysm repair until the abdominal aortic aneurysm diameter is 6 cm or greater, and carotid patients should not undergo revascularization without symptoms.[14,15]

ESRD patients, in general, are known to have a high rate of vascular adverse events, leading to a significantly decreased life span.[9] The most striking and unexpected finding from our study is the rate of postoperative pulmonary complications, rather than the expected vascular complications, likely being the driving force behind the significantly increased postoperative mortality observed in ESRD patients. The higher rate of composite pulmonary outcomes was also the likely driving force behind increased 30-day mortality when comparing elderly ESRD patients with their younger counterparts. After a breakdown by the site of procedure (aortic, carotid, peripheral), composite pulmonary outcomes continued to be significantly more common in ESRD patients undergoing open aortic operations and peripheral vascular surgeries compared with their non-ESRD counterparts. The exact reason for the high rate of pulmonary complications remains unknown and could be an excellent target for future studies.

Although open and endovascular aortic abdominal aortic aneurysm operations had a high rate of complications and death as a group, the breakdown of open and endovascular cases was instructive. The rate of unplanned intubations, reoperations, combined vascular outcome, and death within 30 days continued to be significantly elevated for open aortic cases; however, the risk of developing the same postoperative complications essentially disappeared in patients undergoing endovascular repair, especially after adjustment for the type of anesthesia. These findings argue for the selective use of endovascular techniques while operating on patients with ESRD who are anatomically appropriate candidates. Open abdominal aortic aneurysm repairs should be used highly selectively in the setting of ESRD, given the significantly elevated risk of serious postoperative complications and death.

Peripheral interventions represented the case for the majority of ESRD patients in the analysis. Here, there is no good solution. Critical limb ischemia is a major problem in ESRD populations, and the results of primary amputation are equally poor. Carotid revascularizations in ESRD patients should be done sparingly. In older patients with asymptomatic carotid disease, the ESRD cohort is unlikely to survive long enough to benefit from the prevention of long-term morbidity/mortality. Although via coding analysis, half of the carotid patients had a history of cerebrovascular accident, to be viewed as symptomatic in the randomized carotid trials, the event had to be in the last 4 months[16], and so many of these coded patients likely would not make randomized symptomatic criteria. As much of the morbidity was composite pulmonary outcome, regional anesthetic techniques should be considered while operating on ESRD patients.

Our study has several limitations. This is a retrospective analysis of a prospectively collected database on vascular surgical interventions in a wide variety of academic and community hospitals. The American College of Surgeons National Surgical Quality Improvement Program database represents a sample of operations and is not a consecutive series cohort. Despite a large series of overall patients, the ESRD group represented only about 4% of the sample. The breakdown in age and anatomical groups further reduces the number of patients available for analysis. For example, although we are most critical regarding the performance of aortic and carotid revascularization in the ESRD population, in fact, the number of these cases was quite small compared with the overall population.

Although we excluded any common procedure terminology codes from the analysis associated with the creation or revision of vascular procedures with the purpose of providing access for dialysis, the significantly higher rate of past operations within 30 days and reoperations within 30 days in the case of ESRD patients may have been secondary to the creation or revision of an arterial-venous graft or fistula for dialysis access. Based on the codes used to define ESRD, there is a small chance that some acute renal failures were included. However, with the addition of elective major vascular operations to the study group definition, this becomes unlikely.

As another limitation of the dataset used, we have no way of measuring certain preoperative variables that could push a surgeon to operate on an otherwise high-risk patient. We do not know the size of aortic aneurysms, growth rate, and presence of rest pain, degree of claudication, degree of carotid stenosis, or exact symptoms associated with carotid disease. However, available data and surgeon experience indicate that the majority of abdominal aortic aneurysms and carotid revascularizations are done for asymptomatic disease.

In summary, we found that ESRD patients undergoing elective vascular surgery in the American College of Surgeons National Surgical Quality Improvement Program database have a significantly elevated risk of postoperative complications and death. A minority of these cases are for carotid artery occlusive disease and abdominal aortic aneurysm and performed for predominately asymptomatic indications. Open abdominal aortic aneurysm repair carries a significantly elevated risk of complications and death in ESRD patients. Similarly, the risk of death is significantly elevated after carotid endarterectomy in the ESRD population. Surgeons should strongly consider the increased risk for adverse postoperative outcomes in patients with ESRD requiring major elective vascular intervention—particularly for asymptomatic indications. Future studies identifying the cause for increased pulmonary events should be undertaken to determine whether potential interventions could decrease this very morbid complication after major elective vascular surgery in ESRD patients.

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