From the Midwestern Vascular Surgical Society

Contemporary outcomes of surgical revascularization of the lower extremity in patients on dialysis

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ABSTRACT

Objective: Peripheral arterial disease is a common comorbidity found in up to 38% of patients with end-stage renal disease (ESRD). With an increase in the survival rate of patients with ESRD by >25%, there is a lack of contemporary data on the safety of open surgical revascularization of the lower extremity (OSRLE) in this population of patients. We sought to identify the perioperative morbidity and mortality and independent risk factors of mortality in dialysis patients undergoing OSRLE.

Methods: We reviewed data from 34,941 patients who underwent OSRLE from January 2011 to December 2014 at all hospitals in North America participating in the National Surgical Quality Improvement Program (NSQIP). Trauma, emergencies, aneurysms, and endovascular cases were excluded. We compared the 30-day outcomes of 1623 patients on dialysis with those of 33,318 patients not on dialysis.

Results: Patients on dialysis were younger (66.0 vs 66.7; $P < .01$), were more likely to be treated for critical limb ischemia (49.7% vs 33.1%; $P < .01$), and had more comorbidities compared with patients not on dialysis. Dialysis patients had higher mortality (7.8% vs 2.1%; $P < .01$) and postoperative complication rates after OSRLE, including myocardial infarction (3.5% vs 1.4%; $P < .01$), return to the operating room (6.1% vs 2.8%; $P < .01$), and unplanned readmission (5.2% vs 2.9%; $P < .01$). Although 30-day patency was not different (0.4% vs 0.4%; $P = .56$) between the two study groups, major amputation rate was threefold higher in dialysis patients (1.7% vs 0.57%; $P < .01$). In addition, we identified multiple risk factors that predispose dialysis patients to worse outcome after OSRLE, including older age, African American race, and congestive heart failure. In a subgroup analysis by procedure, dialysis patients who underwent aortobifemoral bypass carried the highest mortality risk (25% vs 3.6%; $P < .01$). Dialysis patients had higher rates of unplanned reoperation (7.9% vs 3.9%; $P < .01$) and unplanned readmission (6.2% vs 3.7%; $P < .01$) and increased length of stay (67.5% vs 47.3%; $P < .01$) after femoral-distal bypass.

Conclusions: With improvements in the medical care of ESRD patients resulting in a large increase in survival rates, little is known about how dialysis patients fare after OSRLE in the contemporary period. Our study shows that despite advances in the medical management of dialysis patients, improvements in outcomes after revascularization have not yet been realized. We found that specific clinical and procedural factors increase the risk for inferior results. Careful selection of dialysis patients suitable for OSRLE according to these risk factors may improve the management of this still high-risk vascular population. (J Vasc Surg 2017;66:167-77.)

Peripheral arterial disease (PAD) is a common comorbidity found in approximately 12% to 38% of patients with end-stage renal disease (ESRD).[1,2] With the increase in ESRD by >600% in the last three decades and with >871,000 patients receiving treatment for ESRD, optimal management of PAD in this group of patients is becoming increasingly important.[3] Controversy still exists as to whether this population of patients is best suited for endovascular treatment, open surgery, or primary amputation in treatment of severe cases of critical limb ischemia.[4]

The past decade has seen advances in the medical management of dialysis patients, with a subsequent increase in the survival rate by >25%.[3] However, with these improving outcomes, there is a paucity of literature studying postoperative outcomes of open surgical revascularization of the lower extremity (OSRLE) in dialysis patients in the last decade, with only a few published series. Thus, it is unclear whether the steady improvement in the survival rate of the dialysis population will translate into increased survival after OSRLE. In addition, these patients often have multiple comorbidities, but little is known about which risk factors have the most unfavorable impact on postoperative morbidity and

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mortality. This study sought to determine the safety of OSRLE in dialysis patients and to identify which patients are at higher risk for complications after surgical revascularization. We hypothesized that despite increased survival rates, patients on dialysis will remain at high risk for complications in the perioperative period and will have worse outcomes after OSRLE compared with patients not on dialysis.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of prospectively collected American College of Surgeons National Surgical Quality Improvement Program (NSQIP) data
- **Take Home Message:** In 34,941 patients who underwent lower extremity revascularization, dialysis patients had higher mortality and more complications, return to the operating room, readmissions, and early amputations than nondialysis patients. Older age, African American race, congestive heart failure, and aortofemoral bypass were associated with adverse outcome.
- **Recommendation:** Dialysis dependence negatively affects outcomes of open vascular surgery for peripheral arterial disease, which is particularly pronounced in patients undergoing aortobifemoral bypass.

METHODS

Data source. The details of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) have been previously described.[5,6] This database provides prospective, risk-adjusted, peer-controlled, and validated information from trained staff that collect preoperative, intraoperative, and postoperative information.[6-8] Morbidity and mortality outcomes within 30 days are included and are obtained if the adverse event occurred during hospitalization, after discharge, or during readmission to another hospital. All postoperative outcomes for the NSQIP are risk adjusted. The Participant Use Data File contains data from cases submitted from 2005 to 2014 at >700 participating sites. Surgical clinical reviewers determine mortality through inspection of medical records, attempts to contact patients a minimum of six times by telephone or mail, and queries of the Social Security Death Index and the National Obituary Archive. This study was deemed exempt from review by the Institutional Review Board at Icahn School of Medicine at Mount Sinai as it uses deidentified data and does not constitute "human subjects research."

Selection of patients. The data set was searched from January 1, 2011, to December 31, 2014. Cases of OSRLE were identified by *Current Procedural Terminology* codes. Major codes included 35355, 35371, 35556, 35566, 35571, 35583, 35585, 35646, 35656, 35661, 35665, and 35666. Trauma, emergency cases, aneurysms, revisions, infected grafts, thromboembolectomies, and endovascular cases were excluded from the study. Each patient in the database is categorized as either "on dialysis" or "not on dialysis." This variable was used to separate the two study groups. Only patients currently receiving a form of renal replacement therapy at the time of surgery were included in the group on dialysis. This category includes both peritoneal dialysis and hemodialysis. Patients with a functional kidney transplant and those with chronic kidney disease (CKD) not yet on dialysis were included in the group not on dialysis.

Statistical analysis. Patients were analyzed on the basis of risk factors, comorbidities, and outcomes. The primary postoperative outcome of interest was 30-day mortality. Secondary postoperative outcomes of interest were total length of stay, mean operative time, and 30-day morbidity, which includes cardiac arrest, myocardial infarction, major amputation, acute renal failure, postoperative pneumonia, postoperative stroke, sepsis, superficial surgical site infection, deep incisional surgical site infection, deep venous thrombosis, pulmonary embolism, urinary tract infection, wound disruption, prolonged ventilation, unplanned reintubation, unplanned return to the operating room, unplanned readmission, and conduit failure. Conduit failure was defined as any graft failure requiring return to the operating room or endovascular intervention within 30 days.

Comorbidities included American Society of Anesthesiologists class, hypertension, diabetes, chronic obstructive pulmonary disease, critical limb ischemia, smoking, congestive heart failure (CHF), previous percutaneous coronary intervention, previous cardiac surgery, prior myocardial infarction within 6 months, prior stroke with neurologic deficit, low preoperative albumin concentration (<3 g/dL), steroid use for chronic condition, bleeding disorder, and disseminated cancer. The NSQIP has one variable for critical limb ischemia that includes rest pain and tissue loss (nonhealing ulceration and gangrene).

To assess for significance in patient demographics, risk factors, and postoperative outcomes, univariate analysis between the dialysis and not on dialysis groups was performed using Pearson χ^2 and Fisher exact tests for categorical variables and Student *t*-test for continuous variables. A *P* value of $< .05$ was considered to be statistically significant. Independent predictors of postoperative events were assessed by multivariate analysis and binary logistic regression using all reported patient demographics and comorbidities as covariates. Multivariate results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). All analyses were performed with SPSS for Macintosh, version 21 (IBM Corp, Armonk, NY).

Table I. Demographics

Variable	All patients (N = 34,941)	Not on dialysis (n = 33,318)	On dialysis (n = 1623)	*P* value
Age, years, mean (SD)	66.6 (11.0)	66.7 (11.0)	66.0 (10.7)	<.01
Male sex	63.6	63.6	62.8	.54
Race				
White	74.8	75.8	53.7	<.01
African American	14.6	13.7	33.0	<.01
Hispanic	3.8	3.7	7.3	<.01
Asian	1.3	1.2	3.6	<.01
Native American	0.2	0.2	0.5	.53
Other	5.3	5.4	2.1	—

SD, Standard deviation.
Values are reported as % unless otherwise indicated.

RESULTS

A total of 37,837 patients who underwent OSRLE were identified from the data set, of which 34,941 met our inclusion and exclusion criteria. Of the 34,941 patients included in this study, 1623 patients were on dialysis and 33,318 patients were not on dialysis. The mean age of patients undergoing OSRLE was 66.0 and 66.7 years ($P < .01$) for patients on dialysis and not on dialysis, respectively (Table I). Of the 34,941 patients studied, 63.6% were male, which was not significantly different between the two groups.

There were a significantly higher percentage of African American patients in the dialysis group (33.0% vs 13.7%; $P < .01$). In addition, many of the identified comorbidities studied were more frequent in the dialysis group (Table II), including hypertension (89.8% vs 81.6%; $P < .01$), diabetes (63.7% vs 36.7%; $P < .01$), and CHF (7.8% vs 2.3%; $P < .01$). However, the incidence of chronic obstructive pulmonary disease was equivalent between the two groups (15.3% vs 15.4%; $P = .91$), and fewer dialysis patients were current smokers (25.8% vs 46.6%; $P < .01$).

The primary indication for intervention was significantly different between the two groups. Dialysis patients more frequently underwent OSRLE for critical limb ischemia than for claudication (49.7% vs 33.1%; $P < .01$). The most common surgical procedure performed was a femoral-distal bypass in 30.4% of all patients, followed by femoral-popliteal bypass with vein in 18.8% of patients (Table III). The distribution of the procedures performed varied between the two study groups. Dialysis patients more frequently underwent a femoral-distal bypass compared with patients not on dialysis (43.3% vs 29.4%; $P < .01$). Aortobifemoral bypass was less frequent in patients on dialysis (1.7% vs 10.3%; $P < .01$). However, there was no difference in the frequency of femoral-popliteal bypass with either vein (18.1% vs 18.9%; $P = .35$) or graft (15.0% vs 15.4%; $P = .62$) between on dialysis and patients not on dialysis, respectively.

The intraoperative and perioperative outcomes between the two groups are listed in Table IV. The mortality rate was 7.8% after OSRLE in dialysis patients, which is significantly higher than the mortality rate of 2.1% for patients not on dialysis ($P < .01$). Patients on dialysis had nearly a twofold increase in mean length of hospital stay (12.8 days vs 6.89 days; $P < .01$). They also experienced a higher rate of perioperative complications in the majority of end points, including myocardial infarction (3.5% vs 1.4%; $P < .01$), postoperative stroke (1.3% vs 0.5%; $P < .01$), sepsis (4.5% vs 1.8%; $P < .01$), pneumonia (3.0% vs 1.8%; $P < .01$), unplanned reintubation (3.8% vs 2.0%; $P < .01$), unplanned return to operating room (6.1% vs 2.8%; $P < .01$), and unplanned readmission (5.2% vs 2.9%; $P < .01$). However, 30-day conduit failure was equal for both groups (0.4% vs 0.4%; $P = .56$), although major amputation rate was threefold higher in dialysis patients (1.7% vs 0.57%; $P < .01$).

Subgroup analysis was performed for mortality, graft failure, major amputation, minor amputation, unplanned reoperation, unplanned readmission, and increased length of stay for each type of procedure performed between patients on dialysis and patients not on dialysis (Fig). Patients on dialysis had a higher rate of mortality for every major procedure performed. This difference was most pronounced for dialysis patients who underwent an aortobifemoral bypass, who had more than a sixfold increase in mortality (25% vs 3.6%; $P < .01$). There was no significant difference in the mortality rate after axillobifemoral bypass between the two groups (12.1% vs 6.8%; $P = .24$). Although graft failure was equivalent between the two study groups, major amputation rate was higher for dialysis patients for almost every procedure performed except for femoral-distal and axillobifemoral bypass. The most pronounced difference in major amputation rate was for aortobifemoral bypass (7.1% vs 0.2; $P < .01$). Dialysis patients who underwent a femoral-distal bypass had the worst outcomes in regard to rates of unplanned reoperations (7.9% vs 3.9%; $P < .01$), minor amputations (4.1% vs 1.6%;

Table II. Comorbidities and clinical presentation

Variable	All patients (N = 34,941)	Not on dialysis (n = 33,318)	On dialysis (n = 1623)	*P* value
ASA classification, mean (SD)	3.17 (0.5)	3.15 (0.4)	3.61 (0.5)	<.01
Hypertension	81.9	81.6	89.8	<.01
Diabetes	38.0	36.7	63.7	<.01
Chronic obstructive pulmonary disease	15.4	15.4	15.3	.91
CKD	—	14.8	—	—
Creatinine level, mg/dL, mean (SD)	—	1.06 (0.54)	—	—
Independent functional status	92.0	92.8	76.6	<.01
Critical limb ischemia	33.8	33.1	49.7	<.01
Smoking	45.7	46.6	25.8	<.01
CHF	2.5	2.3	7.8	<.01
Previous PCI	3.6	3.5	4.7	<.01
Previous cardiac surgery	3.9	3.8	6.1	<.01
Prior myocardial infarction[a]	1.5	1.3	4.5	<.01
Prior stroke[b]	6.5	6.5	7.1	.35
Low preoperative albumin level[c]	7.4	6.5	25.4	<.01
Steroid use for chronic condition	4.2	4.1	6.0	<.01
Bleeding disorder	22.7	22.4	28.3	<.01
Disseminated cancer	0.4	0.4	0.4	.47

ASA, American Society of Anesthesiologists; *CHF,* congestive heart failure; *CKD,* chronic kidney disease; *PCI,* percutaneous coronary intervention; *SD,* standard deviation.
Values are reported as % unless otherwise indicated.
[a]Within 6 months.
[b]With neurologic deficit.
[c]Albumin concentration <3 g/dL.

Table III. Major types of lower extremity revascularization procedures

Procedure	All patients, % (N = 34,941)	Not on dialysis, % (n = 33,318)	On dialysis, % (n = 1623)	*P* value
Femoral-distal bypass	30.4	29.4	43.3	<.01
Femoral-popliteal bypass (vein)	18.8	18.9	18.1	.35
Femoral-popliteal bypass (no vein)	15.4	15.4	15.0	.62
Thromboendarterectomy of common femoral artery	15.0	15.1	15.3	.51
Aortobifemoral bypass	9.9	10.3	1.7	<.01
Femoral-femoral bypass (not vein)	7.6	7.8	4.6	<.01
Axillofemoral bypass	2.9	3.0	2.0	.03

$P < .01$; Fig not included), unplanned readmissions (6.2% vs 3.7%; $P < .01$), and increased lengths of stay (67.5% vs 47.3%; $P < .01$) compared with nondialysis patients. An additional subgroup analysis was performed comparing outcomes in patients with CKD and patients with normal renal function (Table not included). There was a higher 30-day mortality rate in patients with CKD (3.5% vs 1.8%; $P < .01$) but no difference in major amputation rates (0.6% vs 0.5%; $P = .52$) between the two groups.

Three separate multivariate analyses were performed to identify independent predictors of morbidity and mortality for all patients (Table V), dialysis patients (Table VI), and nondialysis patients (Table VII). All demographics, procedures, and comorbidities we identified in Tables I,II, and III were controlled for during these analyses. A separate analysis for each outcome was performed in controlling for all demographics, procedures, and comorbidities. Results from our multivariate analysis showed that dialysis independently predicts more than a threefold increase in mortality after OSRLE (OR, 3.33; CI, 1.98-5.60) in controlling for all demographics, type of procedure, and comorbidities we identified (Table V). In addition, history of myocardial infarction (OR, 2.35; CI, 1.99-5.56), bleeding disorder (OR, 1.66; CI, 1.15-2.39), CKD (OR, 1.65; CI, 1.08-2.54), and older age (OR, 1.04; CI, 1.02-1.06) were also independent predictors of mortality after OSRLE in all patients.

Table IV. Intraoperative data and postoperative outcomes

Variable	All patients (N = 34,941)	Not on dialysis (n = 33,318)	On dialysis (n = 1623)	*P* value
Operative time, minutes, mean (SD)	217.7 (109.7)	216.9 (109.5)	233.17 (111.6)	<.01
Length of hospital stay, days, mean (SD)	7.16 (9.8)	6.89 (9.4)	12.8 (15.0)	<.01
Mortality	2.3	2.1	7.8	<.01
Conduit failure	0.4	0.4	0.4	.56
Major amputation	0.7	0.57	1.7	<.01
Cardiac arrest	0.9	0.8	3.4	<.01
Myocardial infarction	1.5	1.4	3.5	<.01
Acute renal failure	—	0.6	—	—
Postoperative pneumonia	1.8	1.8	3.0	.01
Postoperative stroke	0.5	0.5	1.3	<.01
Sepsis	2.0	1.8	4.5	<.01
Superficial SSI	5.4	5.3	6.5	.03
Deep incisional SSI	2.1	2.1	3.4	<.01
Deep venous thrombosis	0.8	0.8	0.8	.39
Pulmonary embolism	0.2	0.2	0.1	.26
Urinary tract infection	1.5	1.5	1.2	.40
Wound disruption	1.6	1.6	1.7	.78
Prolonged ventilation[a]	1.6	1.5	2.6	.01
Unplanned reintubation	2.1	2.0	3.8	<.01
Unplanned return to operating room	3.0	2.8	6.1	<.01
Unplanned readmission	3.0	2.9	5.2	<.01

SD, Standard deviation; *SSI,* surgical site infection.
Values are reported as % unless otherwise indicated.
[a]Defined as >48 hours.

A separate multivariate analysis was conducted to find significant predictors of postoperative morbidity and mortality in dialysis patients after OSRLE (Table VI). African American race was an independent predictor of mortality (OR, 3.83; CI, 1.24-11.82). Older age was an independent risk factor for both septic shock (OR, 1.28; CI, 1.28-8.08) and mortality (OR, 1.07; CI, 1.01-1.13). Finally, CHF and critical limb ischemia independently predicted increased length of stay (OR, 4.97; CI, 1.08-22.87) and graft failure (OR, 1.84; CI, 1.83-7.49), respectively.

A similar multivariate analysis was performed on patients not on dialysis to find significant independent predictors of postoperative morbidity and mortality (Table VII). Older age, CHF, and critical limb ischemia were again found to be predictive of mortality (OR, 2.25; CI, 1.53-3.30), longer length of stay (OR, 5.09; CI, 3.24-7.98), and graft failure (OR, 1.83; CI, 1.30-2.58), respectively. CKD was also an independent predictor of mortality (OR, 1.67; CI, 1.09-2.56). However, African American race was not an independent predictor of mortality in patients not on dialysis. Aortobifemoral bypass predicted increased length of stay only in patients not on dialysis (OR, 3.98; CI, 3.18-4.98).

DISCUSSION

The cost of treatment for ESRD in the United States exceeded $40 billion in public and private funds in 2009.[3,9] As more than one-third of ESRD patients have PAD, optimal management of this comorbidity will help prevent additional health care expenditure related to complications from treatment. The general population of dialysis patients is at a survival disadvantage, with 1-year and 5-year survival rates as low as 80% and 33%, respectively.[9] However, with advances in medical management, the blunted survival rate of ESRD patients has improved in recent years by >25%.[3] Thus, it is important to re-evaluate the morbidity and mortality of OSRLE in dialysis patients in the modern era. Limited data are available in the last decade on outcomes after OSRLE when the major improvements occurred in the management and survival of dialysis patients.[3] Only three studies looking at OSRLE in dialysis patients were published after 2006. These studies were largely retrospective, with a limited number of patients and end points.

To date, this is the largest study to look at the morbidity and mortality of OSRLE in dialysis patients; it includes multiple risk factor analyses specific to dialysis patients with PAD that have not been described before. Our study shows that OSRLE in dialysis patients in the modern era is associated with a significantly higher 30-day mortality rate of 7.8% in contrast to 2.1% for patients not on dialysis. The elevated mortality risk we found in dialysis patients is lower after femoral-popliteal and femoral-distal bypass and modestly improved overall compared with the

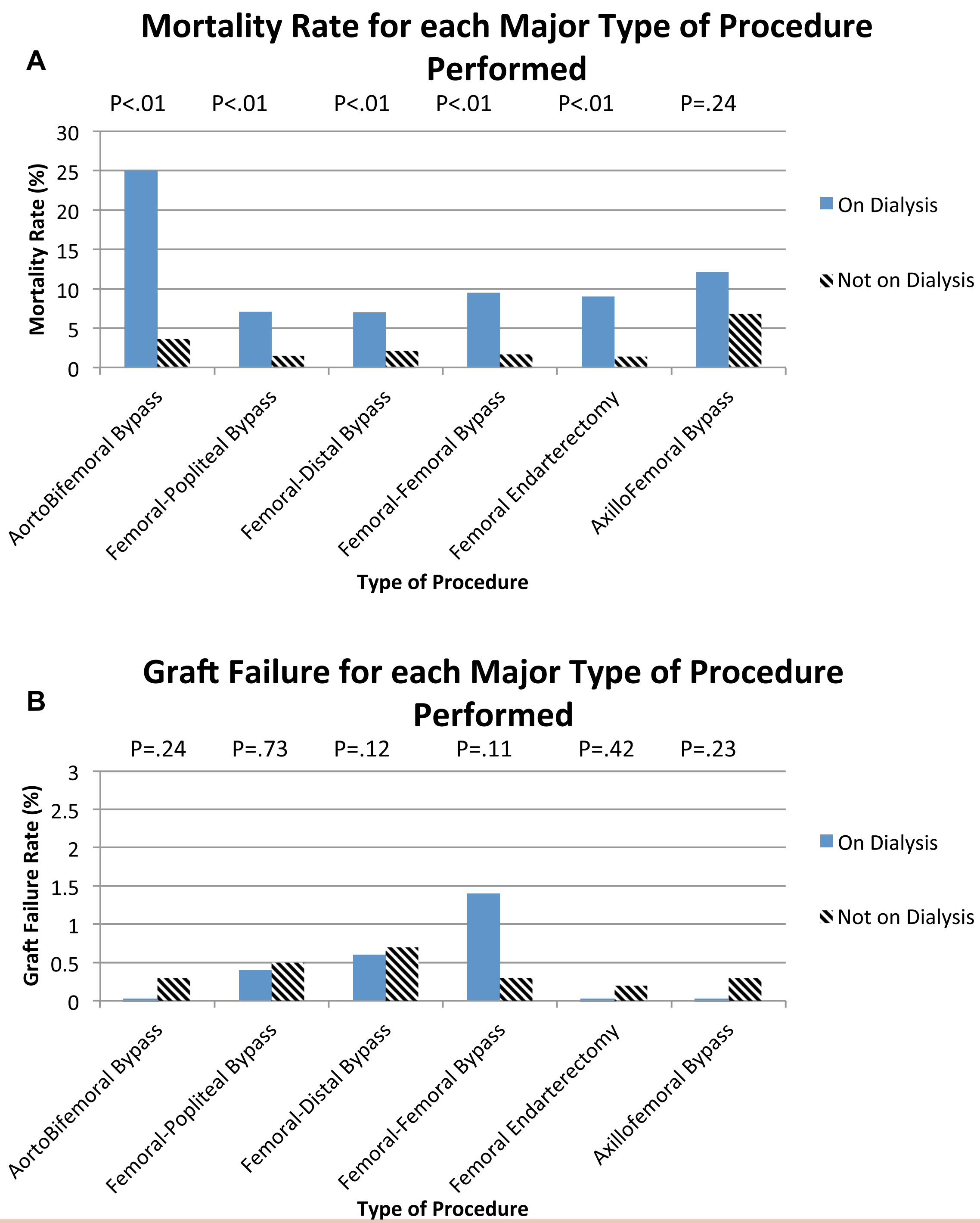
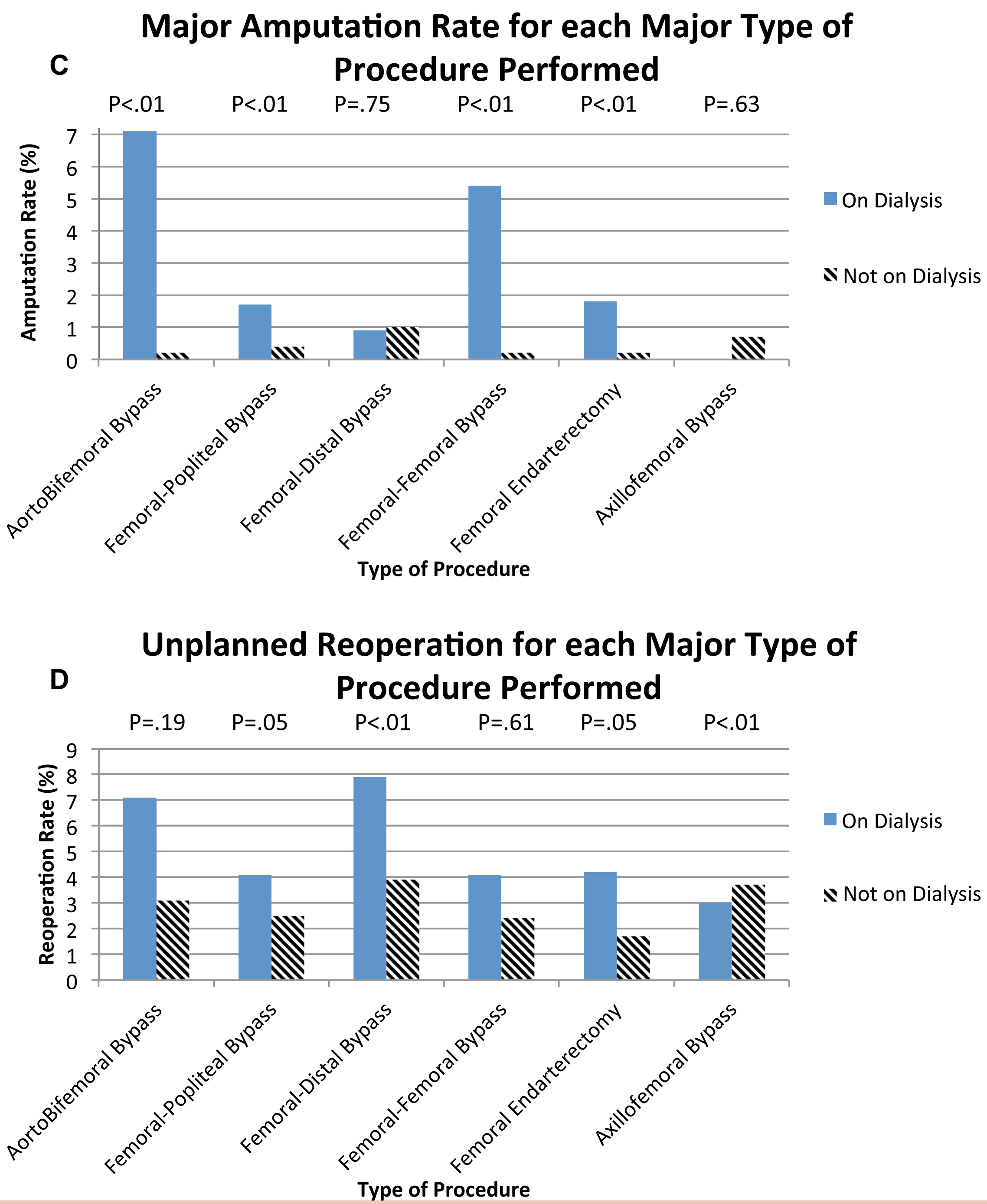


Fig. Outcomes after lower extremity revascularization by procedure for dialysis and nondialysis patients. **A,** Mortality. **B,** Graft failure. **C,** Major amputation. **D,** Unplanned reoperation. **E,** Unplanned readmission. **F,** Increased length of stay (defined as >1 week). Absence of bar height indicates a 0% rate in outcome.

mortality rate in prior studies.[10] A meta-analysis of 1027 ESRD patients undergoing infrainguinal arterial reconstruction from 1987 to 2005 found a perioperative mortality of 8.8%.[11] Thus, although there may have been an improvement in the survival rate of dialysis patients in recent years, morbidity and mortality after open revascularization remain high. This indicates that despite advances in medical management of dialysis patients, open revascularization remains a high-risk procedure.

The reasons that the increased survival rate in dialysis patients has not translated to improved outcomes after OSRLE may be multifactorial. The subset of dialysis patients undergoing OSRLE in the modern era may be more likely to have undergone multiple failed



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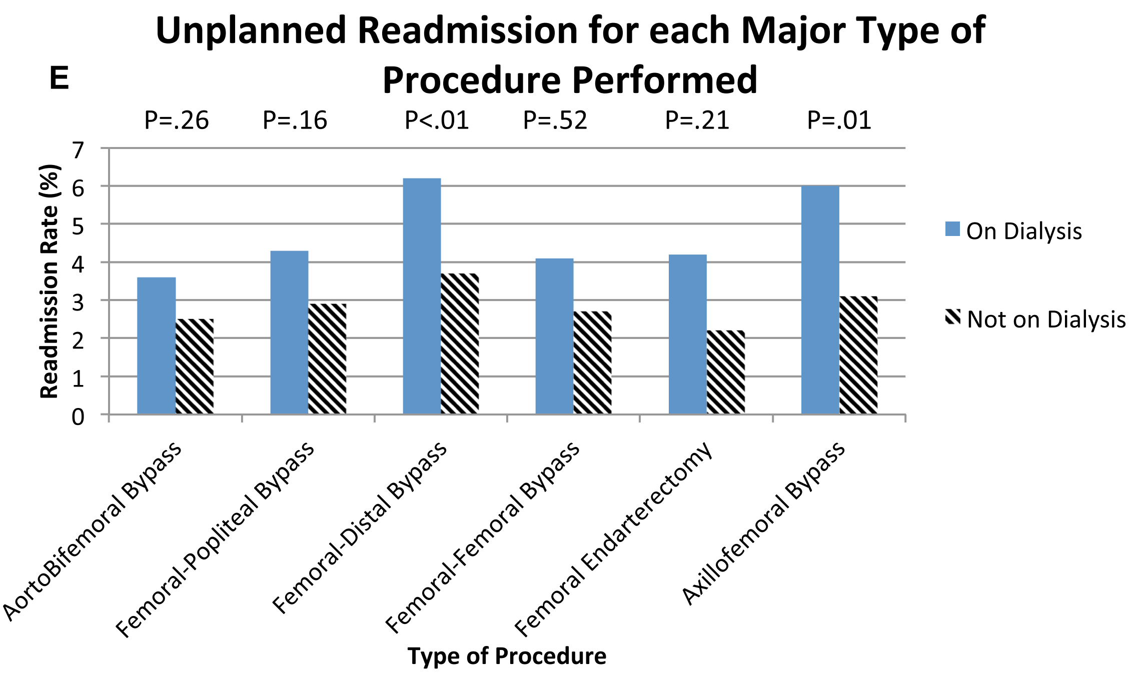
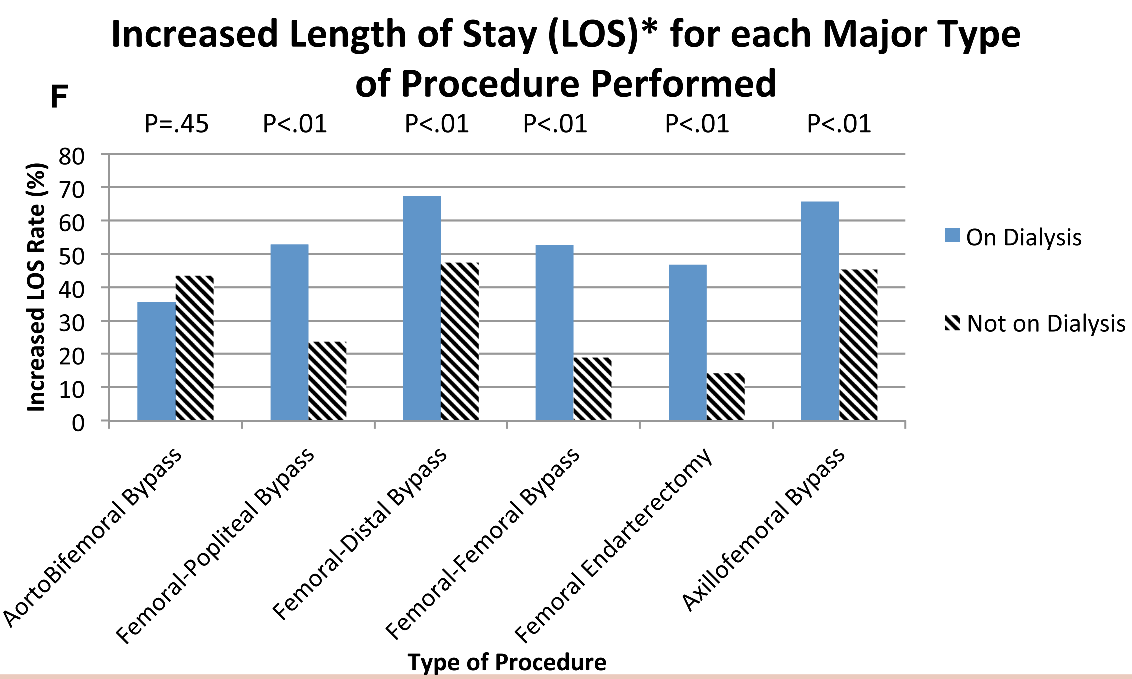
endovascular interventions and to present with more advanced disease. In addition, as the average age of dialysis patients is increasing,[12] we may be operating on older and more fragile patients. This may in part explain why the mean age of dialysis patients in our study is higher by 3 to 5 years compared with earlier studies.[4,11] Finally, dialysis patients still have a blunted compensatory mechanism to the unique physiologic stresses of the postoperative period that puts them at increased risk for complications.

Although dialysis patients still remain at high risk, little is known about what risk factors predispose this population to worse outcomes. Two prior studies have associated age older than 80 years and malnutrition as predictors of poor outcome in dialysis patients after lower extremity bypass surgery.[13,14] Older age was also an independent predictor of poor outcome in our study in addition to CHF and critical limb ischemia for both dialysis and nondialysis patients.





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Our subgroup analysis showed significant variation in mortality and major amputation rate based on the type of procedure performed in dialysis patients. The highest mortality and amputation rates were seen in dialysis patients undergoing aortobifemoral bypass at 25.0% and 7.1% compared with 3.6% and 0.2% for patients not on dialysis, respectively. Although only a few dialysis patients underwent aortobifemoral bypass in our study, these findings suggest that aortobifemoral bypass should be avoided in dialysis patients. In addition, femoral-distal bypass is associated with the highest rates of reoperation, readmission, and length of stay in dialysis patients. However, patency and rate of major amputation are not significantly affected by dialysis status. These findings may in part be explained by interventions for wound complications, minor amputations, and major

Table V. Multivariate analysis to identify most significant independent predictors of mortality in all patients

Risk factors	Event	OR	95% CI	*P* value
Dialysis	Mortality	3.33	1.98-5.60	<.01
History of myocardial infarction	Mortality	2.35	1.99-5.56	.05
Bleeding disorder	Mortality	1.66	1.15-2.39	<.01
CKD	Mortality	1.65	1.08-2.54	.02
Older age[a]	Mortality	1.04	1.02-1.06	<.01

CI, Confidence interval; *CKD,* chronic kidney disease; *OR,* odds ratio.
[a]For each additional year.

Table VI. Multivariate analysis to identify significant independent predictors of morbidity and mortality in dialysis patients

Risk factors	Event	OR	95% CI	*P* value
African American race	Mortality	3.83	1.24-11.82	.02
CHF	Longer length of stay (≥7 days)	4.97	1.08-22.87	.04
Older age[a]	Septic shock	1.28	1.28-8.08	<.01
Older age[a]	Mortality	1.07	1.01-1.13	.01
Critical limb ischemia	Graft failure	1.84	1.83-7.49	<.01

CHF, Congestive heart failure; *CI,* confidence interval; *OR,* odds ratio.
[a]For each additional year.

Table VII. Multivariate analysis to identify significant independent predictors of morbidity and mortality in nondialysis patients

Risk factors	Event	OR	95% CI	*P* value
Aortobifemoral bypass	Longer length of stay (≥7 days)	3.98	3.18-4.98	<.01
CHF	Longer length of stay (≥7 days)	5.09	3.24-7.98	<.01
Older age[a]	Mortality	2.25	1.53-3.30	<.01
Critical limb ischemia	Graft failure	1.83	1.30-2.58	<.01
CKD	Mortality	1.67	1.09-2.56	.02

CHF, Congestive heart failure; *CI,* confidence interval; *CKD,* chronic kidney disease; *OR,* odds ratio.
[a]For each additional year.

amputations outside the 30-day window after femoral-distal bypass.

An interesting finding in our study was that African American race was found to be uniquely predictive of mortality after OSRLE in dialysis patients even when controlling for all other comorbidities and type of procedure. This correlation was not observed in nondialysis patients. Prior studies have described poorer outcomes in minorities after revascularization.[15,16] Limited access to health care resulting in more advanced vascular disease has been shown to play an important role in the racial disparities after revascularization.[17] In addition, there was a significantly higher percentage of African Americans in the dialysis group (33.0% vs 13.7%; $P < .01$), which can be explained by the higher prevalence of hypertension and diabetes mellitus in the African American population.[18]

Despite the increased morbidity and mortality in dialysis patients after OSRLE, the rate of 30-day conduit failure remained low at 0.4% in our study. However, the 30-day amputation rate for dialysis patients was three times higher (1.7% vs 0.57%; $P < .01$) compared with patients not on dialysis. Thus, although OSRLE is a viable option with comparable short-term patency in dialysis patients, this population still suffers from an increased risk of limb loss. The reasons for these findings are unclear but may be related to the sequelae of ESRD, such as microvascular disease, calciphylaxis, and poor wound healing. Although we could not compare long-term outcomes of limb preservation between the two groups outside the 30-day window using the NSQIP, there have been varying results in the literature in regard to long-term patency and limb salvage in the dialysis population, with 1-year amputation-free survival rates ranging from 40% to 80%.[19-23] These findings warrant further research into determining pertinent factors that influence long-term limb salvage in dialysis patients.

Our study has several strengths, including the utility of a large population of patients obtained from a prospectively collected risk-adjusted data set. We also have identified a large number of comorbidities and postoperative complications and have elucidated the differences in outcome between the two study groups for each type of procedure. In addition, we were able to identify unique independent predictors of morbidity and mortality that will guide the decision as to which patients on dialysis should undergo OSRLE.

There are also several limitations in this study pertaining to the NSQIP database. This includes the inability to determine regional or geographic data and a sizable number of patients with no documented indication for surgery. In addition, the NSQIP does not include specific data pertaining to the location and size of the wound and the presence of a foot infection as described in the Wound, Ischemia, and foot Infection (WIfI) classification system. Finally, we were unable to determine long-term survival outside the 30-day window after OSRLE. Reported rates in the literature of long-term survival of dialysis patients after OSRLE are blunted compared with the general PAD population.[24,25] The blunted long-term survival rate may be partly explained by the perioperative risk of surgery, by the complications associated with dialysis, and by the fact that ESRD patients with PAD may have more advanced diffuse atherosclerotic burden, particularly in the coronary and cerebral circulation. However, OSRLE in dialysis patients has also been shown to have a beneficial impact on overall survival at 1 year.[25] Future research is needed to determine the long-term survival rates and outcomes of less invasive measures in ESRD patients in the modern era after OSRLE.

CONCLUSIONS

ESRD patients have seen a marked improvement in survival rates by >25% in the last decade because of improved medical care. Given the paucity of literature in the modern era, it is unclear whether these improvements in medical management translate into improvements after OSRLE. Our study shows that OSRLE in dialysis patients is still associated with a significant increase in morbidity and mortality in the contemporary period. The patency after OSRLE may not be negatively affected by dialysis, although there is an increased risk of major amputation at 30 days. Careful selection of patients is thus important to determine which patients will benefit most from open revascularization. We have identified several independent predictors of morbidity and mortality that should guide the physician's decision as to which dialysis patients are better suited for open revascularization.

AUTHOR CONTRIBUTIONS

Conception and design: AR, MM, PF, AV
Analysis and interpretation: AR, MB, JC, MM, PF, AV
Data collection: AR, JC
Writing the article: AR, MB, JC, AV
Critical revision of the article: MB, MM, PF, AV
Final approval of the article: AR, MB, JC, MM, PF, AV
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