# Death and Postoperative Complications After Hip Fracture Repair: Dialysis Effect

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**Introduction:** It is unknown whether patients receiving dialysis have a higher morbidity and mortality risk after hip fracture repair conferred by their kidney failure or by the high comorbidity burden often present.

**Methods:** We examined associations of dialysis dependency with postoperative complications, death, and readmission in a matched cohort study of U.S. patients undergoing hip fracture repair, from January 2010 to December 2013, in the American College of Surgeons National Surgical Quality Improvement Program. Matching included sex, age, race, diabetes mellitus, operation year, primary surgery type, and anesthesia technique.

**Results:** Among 22,621 patients, 377 dialysis-dependent patients were matched to 1508 nondialysis patients. Median age was 78 years (interquartile range = 68−85) years, 56% were men, 70% were white, 43% had diabetes, and 47% underwent fracture fixation under mostly (80%) general anesthesia. Dialysis-dependent patients had higher physical status classification, had more heart failure and hypoalbuminemia, and were less often smokers. After adjustment, a greater risk of prolonged postoperative stays beyond 7 days (odds ratio [OR] = 1.43, 95% confidence interval [CI] = 1.09−1.89), higher in-hospital mortality (OR = 3.13, CI = 1.72−5.7), and 30-day death (OR = 2.29, CI = 1.51−3.48) but not 30-day readmission (P = 0.09) was observed with dialysis dependency. Adjusted analyses in the original cohort (n = 22,621) were similar: the dialysis group had greater risk of prolonged postoperative stay (OR = 1.77, CI = 1.42−2.21), in-hospital mortality (OR = 2.65, CI = 1.74−4.05), and 30-day death (OR = 2.03, CI = 1.48−2.80) and 30-day readmission (OR = 1.62, CI = 1.66−2.26).

**Conclusion:** Dialysis dependency is associated with an increased risk of death and postoperative complications after hip fracture repair. These findings have implications for case-mix adjustment and quality metrics.

Hip fracture is a major public health concern in the United States and worldwide.[1−4] Importantly, the burden of hip fracture is disproportionately experienced by individuals with end-stage renal disease (ESRD).[5,6] In 2010, older hemodialysis (HD) patients had nearly 4 times the fracture rate (31.9 vs. 8.0 events/1000 persons-years) of

similarly aged nonhemodialysis patients in the Medicare population.[5,6] This increased risk of fracture has been attributed to altered bone mineralization and metabolism, skeletal fragility, impaired muscle strength, and a propensity for falls.[7−13] The effect of hip fracture is further compounded by an abundance of pre-existing comorbidities and postoperative complications leading to subsequent hospitalizations and death compared to the general age-, race-, and sex-matched population,[5,6,14−25] and may have a graded increase in risk with fall in kidney function.[20] Although patients with kidney failure represent a group at high risk for death and surgical complications, what remains unclear from these past studies is whether

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it is the dialysis-dependent kidney failure or the high co-morbidity burden seen in dialysis patients that contributes to the adverse outcomes. Thus, we sought to determine whether dialysis dependency is an independent predictor for postoperative outcomes including death, hospital stay and readmission after hip fracture repair beyond the multimorbidity common in these patients by using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP), a database of multiple surgical centers across the United States that collects outcomes data for 30 days following surgical procedures.[26,27]

## MATERIALS AND METHODS

### Study Design, Data Source, and Cohort Selection

A matched cohort study was performed using the ACS-NSQIP database. The ACS-NSQIP, a nationally validated, risk-adjusted surgical outcomes database, prospectively collects data on preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major surgical procedures in both the inpatient and outpatient settings.[28] The surgical quality improvement program, consisting of more than 350 participating U.S. hospitals, uses trained surgical clinical reviewers for each site to collect data extending from the preoperative through the full 30-day postoperative period, regardless of dismissal date, on randomly assigned patients in an effort to minimize selection bias.[29] The number and types of variables collected differ from hospital to hospital, depending on the hospital's size, patient population, and quality improvement focus. Blinded, risk-adjusted data are then provided back to the participating hospitals, allowing them to nationally benchmark their complication rates and surgical outcomes. Participant use data files from the NSQIP were queried for surgical treatment of hip fracture with fracture fixation or hip arthroplasty from 1 January 2010 through 31 December 2013. All hip fracture cases were identified through primary postoperative diagnoses (International Classification of Diseases, Ninth Revision [ICD-9] diagnosis 820.xx (N = 25,458). The study cohort was limited to patients undergoing primary procedure for fracture fixation (n = 11,556) or hip arthroplasty repair (n=12,114) (Figure 1). Fracture fixation was defined using the following Current Procedural Terminology (CPT) codes: (i) CPT 27235 (percutaneous treatment of femoral fracture [n = 509]); (ii) CPT 27244 (treatment of intertrochanteric, pertrochanteric, or subtrochanteric femoral fracture; with plate/screw type implant, with or without cerclage [n =3918]); or (iii) CPT 27245 (treatment of

intertrochanteric, peritrochanteric, or subtrochanteric femoral fracture; with intramedullary implant, with or without interlocking screws and/or cerclage [n = 7129]). Hip arthroplasty was defined as follows: (i) CPT 27125 (partial hip replacement with or without bipolar prosthesis [n = 4405]); (ii) CPT 27130 (total hip replacement [n = 1106]); or (iii) CPT 27236 (open treatment of femoral fracture, proximal end, neck, internal fixation, or prosthetic replacement [n = 6603]). CPT and ICD codes were consistent with prior investigations assessing patient outcomes following hip fracture repair.[25]

### Exclusion Criteria

Cases were excluded for the following reasons: concomitant knee procedures (n = 1), cases missing description of sex, age, year of operation, anesthesia technique, or race (subtotal n = 28), disseminated cancer (n = 390), central nervous system tumor (n = 8), preoperative hospital stay >14 days (n = 83), open hip fracture (n = 228), primary procedure surgeon's specialty other than orthopedic (n = 122), and cases having concomitant procedure of fracture fixation (if having primary procedure for arthroplasty) or arthroplasty (if primary procedure for fracture fixation) (n = 48). Dialysis dependency was defined as kidney failure requiring treatment with peritoneal dialysis, hemodialysis, hemofiltration, hemodiafiltration, or ultrafiltration within 2 weeks prior to the principal operative procedure. To restrict to an eligible study population receiving chronic hemodialysis therapy, cases with acute renal failure requiring dialysis/filtration (n = 141 were also excluded).

### Matching Criteria

To account for the independent effect of dialysis in this cohort, individual dialysis cases were matched to 4 nondialysis controls (1:4) (Figure 2). Patients were matched on sex (male/female), age (± 5 years), year of operation (±1 years), primary procedure type (fracture fixation/arthroplasty), anesthesia technique (general/nongeneral technique), race (white/black/other), and diabetes mellitus (yes/no).

### Outcomes, Follow-up, and Predictors

The outcomes included the following: prolonged postoperative length of hospital stay (PLOS), in-hospital death, death within 30 days of hip fracture repair, and in a subset of patients (years 2011−2013) 30-day postoperative readmission rate. PLOS was defined as any postoperative hospital length of stay >7 days (above the 75th percentile of overall length of hospital stay). Major postoperative complication was defined as any postoperative deep/incisional surgical site infection organ/space surgical site infection, wound dehiscence, pneumonia, unplanned reintubation, pulmonary embolism,
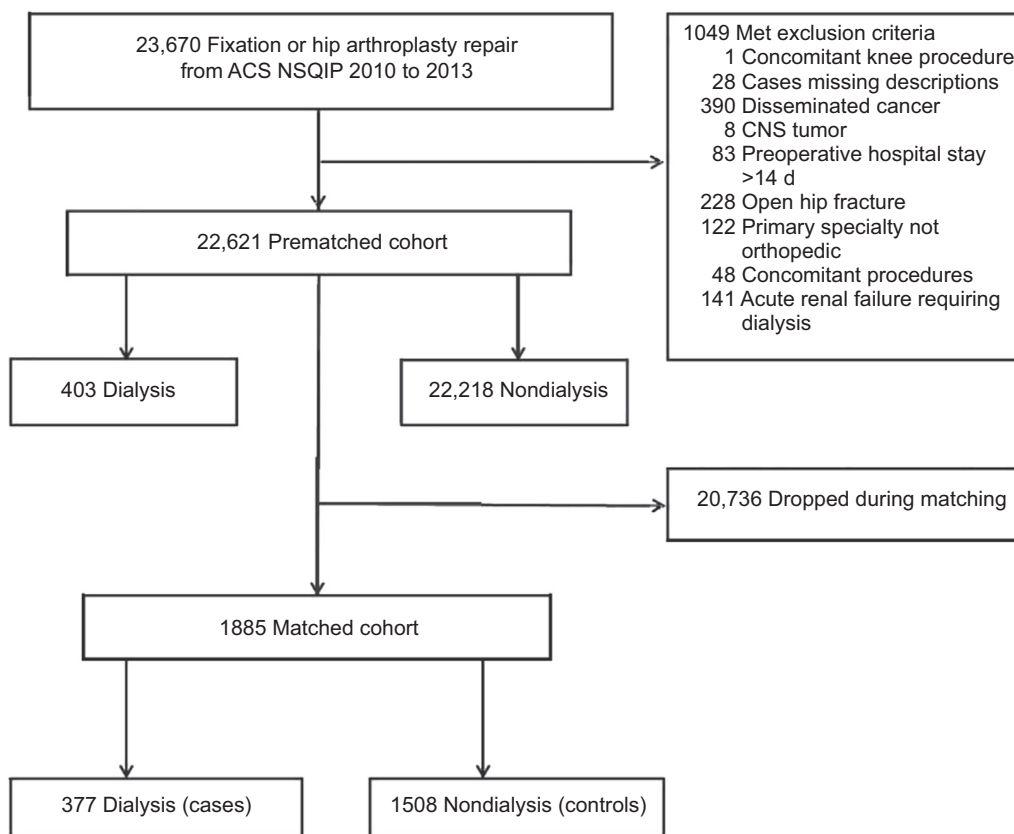
**Figure 1.** Study flow diagram of inclusion, exclusion, and cohort-matching. ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; CNS, central nervous system.

ventilator use >48 hours, progressive renal insufficiency, acute renal failure, cerebrovascular accident/stroke with neurological deficit, cardiac arrest, myocardial infarction, deep venous thrombosis/thrombophlebitis, sepsis or septic shock, or return to operating room. In 2011, NSQIP began capturing detailed data on 30-day postoperative readmissions following surgical procedures. Hospital readmission was defined by the NSQIP database as hospitalization in the original hospital or another medical center within 30 days following the surgical procedure. Beginning in 2012, the primary suspected reason for and number of unplanned (related or unrelated) readmissions postoperatively were recorded. Time from discharge to readmission was not captured in the database until 2012, and therefore the Cox proportional hazard model of time to readmission

includes data from 2012 to 2013 only (n = 1363; 264 dialysis-dependent). All postoperative complications and study follow-up were based on the NSQIP database design from the time of surgery to 30 days.

### Baseline Demographics and Covariates

Baseline demographics and covariates were recorded for each patient. Several comorbidities were defined in the ACS-NSQIP based on their occurrence before the surgical procedure, including congestive heart failure (within 30 days), active smoking status (within 1 year), and greater than 10% weight loss (within 6 months). Preoperative kidney function was assessed with creatinine values (within 90 days). Estimated glomerular filtration rate was calculated using the 4-variable Modification of Diet in Renal Disease equation.[30] American Society of Anesthesiologists (ASA) Physical Status Classification System score is a scoring system designed to standardize physical status classification during the preoperative risk assessment.[31] The scoring system uses 5 classes to describe the patient's physical state: No Disturbance (Class 1), Mild Disturbance, Severe Disturbance, Life Threatening, and Moribund. In this study, ASA class was grouped as <4 (ASA I [normal healthy patients] to ASA III (those with severe systemic disease not with constant threat to life) or ≥4

**Matching criteria (1 dialysis: 4 nondialysis):**
 Age ± 5 yr
 Sex (male/female)
 Race (white/black/other)
 Diabetes (yes/no)
 Primary procedure type (fracture fixation/arthroplasty)
 Year of operation ±1 yr
 Anesthesia technique (general/nongeneral)

**Figure 2.** Matching criteria for cases and controls.

(patients with severe systemic disease that is a constant threat to life and moribund patients who are not expected to survive without the operation). The systemic inflammatory response syndrome (SIRS) is a widespread inflammatory response to a variety of severe clinical insults. This syndrome is clinically recognized by the presence of 2 or more of the following within the same time frame: (i) temperature $>38\,°C$ (100.4 $°F$) or $<36\,°C$ (96.8 $°F$); (ii) heart rate $>90$ bpm, respiratory rate $>20$ breaths/min, or $PaCO_2$ $<32$ mm Hg($<4.3$ kPa); (iii) white blood cell count $>12,000$ cell/mm$^3$, $<4000$ cells/mm$^3$, or $>10\%$ immature (band) forms; or (iv) anion gap acidosis. Sepsis was defined as SIRS plus either positive blood culture results or suspected preoperative clinical condition of infection.

## Statistical Analyses

Kaplan−Meier 30-day survival curves were plotted for dialysis and nondialysis patients and compared using the log-rank method. Logistic regression was used to assess the associations between predictors (dialysis dependency) and in-hospital mortality, major postoperative complications, PLOS, and 30-day mortality in all patients undergoing the procedure from 2010 to 2013. Patients were at risk for readmission only after live hospital discharge and up to 30 days after the index surgery, excluding time spent in the hospital during readmission (estimated to be 2 days per readmission). Multivariable logistic regression models for predicting binary outcomes and Cox proportional hazards readmission models included age, sex, ASA class, heart failure, chronic obstructive pulmonary disease, functional status, body mass index, and preoperative white blood cell count and albumin value based on clinical significance and results of the univariate analyses. In the multivariable models, missing preoperative characteristics were imputed using multiple imputation for each respective covariate having missing data.

To examine the association between dialysis dependency and risk of outcomes in a "typical sample" of unmatched patients, additional analyses were repeated in the entire (matched and prematched) ACS NSQIP cohort from 2010 to 2013. To examine the association between dialysis dependency and risk of outcomes when the matching criteria included ASA class (groups 1−2 and 3−4), additional analyses were repeated for the same outcomes of interest. Logistic regression was used to assess the association between dialysis and 30-day mortality, in-hospital mortality, major postoperative complications, and PLOS. Cox proportional hazards models were used to assess readmissions within 30 days of index hip fracture procedure in the 2012 to 2013 cohorts given availability of data on time from discharge. All statistical comparisons were assessed at

$P < 0.05$. All analyses were performed in SAS version 9.3 (SAS Institute Inc., Cary, NC).

## RESULTS

### Demographic and Laboratory Characteristics

A total of 23,670 patients were identified who underwent a primary procedure for fracture fixation (n = 11,556) or hip arthroplasty repair (n = 12,114) from 2010 through 2013. After 1049 exclusions, 22,621 patients met the inclusion criteria (prematched cohort) (Figure 1). Of these, 377 dialysis-dependent patients (cases) were matched to 1508 non−dialysis-dependent controls. Baseline patient characteristics and laboratory tests of the matched cohort are shown in Table 1. The matched cohort comprised mostly elderly (median age, 78 years), white (70.0%) men (55.7%) with a high prevalence of diabetes mellitus (43.0%). Dialysis-dependent patients had higher ($\geq 4$) ASA classes (56.5% vs. 18.6%; $P < 0.001$) and more often had CHF in the 30 days before surgery (8.2% vs. 3.7%; $P < 0.001$) but were less often smokers (12.2% vs 16.4%; $P = 0.04$). As expected, both serum creatinine and blood urea nitrogen values were higher, and hematocrit and serum albumin values were lower, in the dialysis group (all $P < 0.001$). Significant differences in laboratory studies were also observed for platelet count ($P = 0.02$) and alkaline phosphatase and serum glutamic oxaloacetic transaminase (both $P < 0.001$).

### Postoperative Outcomes

Hip fracture repair procedure, hospital stay, and postoperative complications are shown in Table 2. In the matched cohort, 53.3% had arthroplasty procedures and 46.7% underwent fracture fixation, with 79.8% of all procedures using general anesthesia. The surgical procedures occurred in 2012 and 2013 for 72.3% of patients. For the overall cohort, mean (SD) hospital duration was 1.37 (1.46) days from hospital admission to operation, 6.53 (7.37) days from operation to discharge, and 7.90 (7.73) days for the total hospital stay. A minority of patients had prolonged PLOS from operation to discharge: 22.7% for $>7$ days, 7.5% for $>14$ days, and 4.4% for $>20$ days. The dialysis group was at greater risk for PLOS $>7$ days compared with the nondialysis group (OR = 1.82; 95% CI = 1.42−2.34; $P < 0.001$). Urinary tract infection occurred less often in dialysis (2.7%) than in nondialysis (5.6%) patients ($P = 0.020$). After adjustment for age, sex, ASA class, history of chronic obstructive pulmonary disease, history of congestive heart failure, functional dependency, body mass index, preoperative albumin, and preoperative platelets, dialysis dependency was still associated with an increased risk of PLOS $>7$ days (adjusted OR = 1.43, CI = 1.09−1.89, $P = 0.01$).

**Table 1.** Baseline characteristics and laboratory tests in dialysis-dependent patients and matched nondialysis patients undergoing hip fracture repair (American College of Surgeons National Surgical Quality Improvement Program [NSQIP] 2010–2013)

| Baseline characteristics and laboratory tests[a] | Dialysis (n = 377) | Nondialysis (n = 1508) | Total (n = 1885) | P value |
|---|---|---|---|---|
| Age, yr, median (IQR) | 77 (67–84) | 78 (68–85) | 78 (68–85) | 0.068 |
| Male sex | 210 (55.7) | 840 (55.7) | 1050 (55.7) | 1.00 |
| Race | | | | 1.00 |
|   White | 264 (70.0) | 1056 (70.0) | 1320 (70.0) | |
|   Black or African American | 24 (6.4) | 96 (6.4) | 120 (6.4) | |
|   Other | 89 (23.6) | 356 (23.6) | 445 (23.6) | |
| Diabetes | 162 (43.0) | 648 (43.0) | 810 (43.0) | 1.00 |
| ASA class | | | | <0.001 |
|   1 (No Disturbance) | 1 (0.3) | 19 (1.3) | 20 (1.1) | |
|   2 (Mild Disturbance) | 5 (1.3) | 246 (16.3) | 251 (13.3) | |
|   3 (Severe Disturbance) | 158 (41.9) | 959 (63.7) | 1117 (59.4) | |
|   4 (Life Threatening) | 209 (55.4) | 279 (18.5) | 488 (25.9) | |
|   5 (Moribund) | 4 (1.1) | 2 (0.1) | 6 (0.3) | |
| History of severe COPD | 63 (16.7) | 201 (13.3) | 264 (14.0) | 0.091 |
| CHF in the 30 days before surgery | 31 (8.2) | 56 (3.7) | 87 (4.6) | <0.001 |
| Current smoker within 1 yr | 46 (12.2) | 248 (16.4) | 294 (15.6) | 0.042 |
| >10% loss body weight in past 6 months | 6 (1.6) | 18 (1.2) | 24 (1.3) | 0.54 |
| Totally or Partially Dependent Functional Status | 97 (26.1) | 367 (24.6) | 464 (24.9) | 0.55 |
| Systemic sepsis | 6 (1.6) | 12 (0.8) | 18 (1.0) | 0.26 |
| Body mass index, kg/m$^2$, median (IQR) | 24.74 (21.8–29.0) | 25.2 (21.9–29.2) | 25.1 (21.9–29.1) | 0.79 |
|   ≥30 | 67 (20.3) | 283 (21.7) | 350 (21.4) | 0.59 |
|   n (%) missing | 47 (12.5) | 202 (13.4) | 249 (13.2) | |
| Preoperative laboratory tests | | | | |
| Serum creatinine, mg/dl, median (IQR) | 4.8991 (3.77–6.2) | 0.93 (0.72–1.25) | 1.052 (0.8–1.9) | <0.001 |
| BUN, median (IQR) | 38 (26–53.11065) | 19.6078 (14–27) | 22 (15–31.9328) | <0.001 |
|   ≥33 | 228 (60.6) | 211 (14.2) | 439 (23.6) | <0.001 |
| White blood cell count, median (IQR) | 8.9 (7.1–11.35) | 9.3 (7.5–11.8) | 9.2 (7.4–11.7) | 0.11 |
|   ≥10 K/mm$^3$ | 140 (37.2) | 643 (43.1) | 783 (41.9) | 0.039 |
| Hematocrit, median (IQR) | 32.4 (29.4–36) | 35.5 (31.9–38.9) | 35 (31.1–38.3) | <0.001 |
|   <30 | 104 (28.1) | 231 (15.7) | 335 (18.2) | <0.001 |
| Platelet count, median (IQR) | 177 (133–240) | 192 (153–239) | 189 (149–239) | 0.021 |
|   <250 K/mm$^3$ | 297 (79.2) | 1169 (78.7) | 1466 (78.8) | 0.82 |
| Serum albumin, g/dl, median | 3.3 (2.9–3.7) | 3.5 (3.1–3.9) | 3.5 (3.1–3.8) | <0.001 |
|   <3/5 g/dl | 169 (60.1) | 392 (44.2) | 561 (48.0) | <0.001 |
|   n (%) missing | 96 (25.5) | 621 (41.2) | 717 (38.0) | |
| Alkaline phosphatase, median (IQR) | 102 (78–134) | 79 (65–102) | 84 (67–110) | <0.001 |
|   n (%) missing | 118 (31.3) | 693 (46.0) | 811 (43.0) | |
| SGOT, median (IQR) | 21 (16–28) | 23 (18–30) | 23 (18–30) | <0.001 |
|   n (%) missing | 135 (35.8) | 697 (46.2) | 832 (44.1) | |
| Total bilirubin, median (IQR) | 0.6 (0.4–0.8) | 0.6 (0.4–0.8) | 0.6 (0.4–0.8) | 0.18 |
|   n (%) missing | 143 (37.9) | 701 (46.5) | 844 (44.8) | |

ASA, American Society of Anesthesiologists; BUN, blood urea nitrogen; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; SGOT, serum glutamic oxaloacetic transaminase (also known as aspartate aminotransferase [AST]).
Values are n (%) unless otherwise specified. Patients were matched on sex, age (±5 yr), race, diabetes mellitus, year of operation (±1 yr), primary procedure type (fracture fixation/arthroplasty), and anesthesia technique (general/nongeneral technique).
[a]Data missing for the following (% of total): ASA class (0.2%), serum creatinine (2.2%), BUN (1.3%), white blood cell count (1.0%), hematocrit (2.3%), platelet count (1.3%), serum albumin (38.0%), alkaline phosphatase (43%), SGOT (44.1%), and total bilirubin (44.8%).

## Major Complications

The most common complications included pneumonia (3.8%), in-hospital death (3.0%), and sepsis/septic shock (2.8%) (Table 2). Rates of events were significantly higher in the dialysis group for cardiac arrest requiring cardiopulmonary resuscitation (4.5% vs. 0.7%; $P < 0.001$) and sepsis/septic shock (5.3% vs. 2.2%, $P = 0.001$), and were lower in the dialysis group for urinary tract infection (2.7% vs. 5.6%, $P = 0.02$). Dialysis dependency was associated with an increased risk of major complication following hip fracture repair (unadjusted OR = 1.74, CI = 1.29-−2.34), $P < 0.001$), which persisted after adjustment (adjusted OR = 1.44, CI = 1.03−2.006, $P = 0.03$).

## Death

Overall, 56 patients (3.0%) died prior to hospital discharge, with a higher proportion of deaths occurring in the dialysis-dependent group (7.7% vs. 1.8%, $P < 0.001$). In-hospital mortality during the index

**Table 2.** Hip fracture repair, hospital stay, and postoperative complications in dialysis-dependent patients and matched nondialysis patients undergoing hip fracture repair (American College of Surgeons National Surgical Quality Improvement Program [NSQIP] 2010–2013)

| Surgical procedure and complications[a] | Dialysis (n = 377) | Nondialysis (n = 1508) | Total (n = 1885) | P value |
|---|---|---|---|---|
| Primary CPT procedure | | | | 1.00 |
| Arthroplasty (CPT codes 27125, 27130, 27236) | 201 (53.3) | 804 (53.3) | 1005 (53.3) | |
| Fracture fixation (CPT codes 27235, 27244, 27245) | 176 (46.7) | 704 (46.7) | 880 (46.7) | |
| General anesthesia | 301 (79.8) | 1204 (79.8) | 1505 (79.8) | 1.00 |
| Principal anesthesia technique (collapsed) | | | | 0.84 |
| Epidural/spinal | 70 (18.6) | 276 (18.3) | 346 (18.4) | |
| General | 301 (79.8) | 1204 (79.8) | 1505 (79.8) | |
| Nerve block (local or regional) | 1 (0.3) | 11 (0.7) | 12 (0.6) | |
| Monitored anesthesia care/i.v. sedation | 5 (1.3) | 16 (1.1) | 21 (1.1) | |
| None | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Other | 0 (0.0) | 1 (0.1) | 1 (0.1) | |
| Year of operation | | | | 0.41 |
| 2010 | 33 (8.8) | 119 (7.9) | 152 (8.1) | |
| 2011 | 80 (21.2) | 290 (19.2) | 370 (19.6) | |
| 2012 | 112 (29.7) | 515 (34.2) | 627 (33.3) | |
| 2013 | 152 (40.3) | 584 (38.7) | 736 (39.0) | |
| Hospital stay: | | | | |
| Days from hospital admission to operation | | | | 0.003 |
| Mean (SD) | 1.57 (1.78) | 1.32 (1.37) | 1.37 (1.46) | |
| Median (IQR) | 1 (1–2) | 1 (1–2) | 1 (1–2) | |
| Range | 0 to 14 | 0 to 13 | 0 to 14 | |
| Time from admission to operation >2 days | 53 (14.1) | 165 (10.9) | 218 (11.6) | 0.091 |
| Days from operation to discharge | | | | <0.001 |
| n (%) missing | 4 (1.1) | 2 (0.1) | 6 (0.3) | |
| Mean (SD) | 8.14 (8.64) | 6.13 (6.97) | 6.53 (7.37) | |
| Median (IQR) | 5 (4–9) | 4 (3–6) | 4 (3–7) | |
| Range | 0 to 64 | 0 to 76 | 0 to 76 | |
| Length of total hospital stay | | | | <0.001 |
| Mean (SD) | 9.71 (9.15) | 7.45 (7.28) | 7.90 (7.73) | |
| Median (IQR) | 7 (5–11) | 5 (4–8) | 6 (4–9) | |
| Range | 1 to 75 | 0 to 77 | 0 to 77 | |
| Days from operation to discharge >7 | 119 (31.9) | 308 (20.5) | 427 (22.7) | <0.001 |
| Days from operation to discharge >14 | 45 (11.9) | 96 (6.4) | 141 (7.5) | <0.001 |
| Days from operation to discharge >20 | 28 (7.4) | 54 (3.6) | 82 (4.4) | 0.001 |
| Postoperative complications | | | | |
| In-hospital death | 29 (7.7) | 27 (1.8) | 56 (3.0) | <0.001 |
| Superficial SSI | 3 (0.8) | 18 (1.2) | 21 (1.1) | 0.78 |
| Deep incisional SSI | 1 (0.3) | 8 (0.5) | 9 (0.5) | 0.70 |
| Organ space SSI | 3 (0.8) | 2 (0.1) | 5 (0.3) | 0.058 |
| Wound disruption | 1 (0.3) | 1 (0.1) | 2 (0.1) | 0.36 |
| Pneumonia | 14 (3.7) | 58 (3.8) | 72 (3.8) | 0.90 |
| Unplanned intubation | 13 (3.4) | 29 (1.9) | 42 (2.2) | 0.073 |
| Pulmonary embolism | 2 (0.5) | 13 (0.9) | 15 (0.8) | 0.75 |
| Ventilator >48 h | 6 (1.6) | 13 (0.9) | 19 (1.0) | 0.20 |
| Urinary tract infection | 10 (2.7) | 84 (5.6) | 94 (5.0) | 0.020 |
| Cardiac arrest requiring CPR | 17 (4.5) | 11 (0.7) | 28 (1.5) | <0.001 |
| Myocardial infarction | 11 (2.9) | 28 (1.9) | 39 (2.1) | 0.20 |
| DVT/thrombophlebitis | 1 (0.3) | 13 (0.9) | 14 (0.7) | 0.33 |
| Sepsis | 12 (3.2) | 26 (1.7) | 38 (2.0) | 0.071 |
| Septic shock | 8 (2.1) | 7 (0.5) | 15 (0.8) | 0.001 |
| Sepsis or septic shock | 20 (5.3) | 33 (2.2) | 53 (2.8) | 0.001 |
| Peripheral nerve injury | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Graft/prosthesis/flap failure | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Readmission within 30 days of index procedure (2011–2013) | 48 (14.0) | 125 (9.0) | 173 (10.0) | 0.006 |

CPR, cardiopulmonary resuscitation; CPT, Current Procedural Terminology; DVT, deep venous thrombosis; IQR, interquartile range; SSI, surgical site infection.
Values are n (%) unless otherwise specified. Patients were matched on sex, age (±5 yr), race, diabetes mellitus, year of operation (±1 yr), primary procedure type (fracture fixation/arthroplasty), and anesthesia technique (general/nongeneral technique).
[a]Data missing for the following (% of total): length of stay 0.3%.

hospitalization was associated with a more than 3-fold increased adjusted risk in dialysis-dependent patients (adjusted OR = 3.13, CI = 1.72−5.70, $P < 0.001$). The cumulative 30-day mortality rate was 7.4% for the total cohort but was significantly higher in dialysis group (14.3% [54/377], vs. 5.7% [86/1,508] for nondialysis; $P < 0.001$) and is further illustrated in Figure 3. Overall, the risk of death within 30 days of procedure was greater in the dialysis group (adjusted OR = 2.29, CI = 1.51−3.48, $P < 0.001$).

### Readmissions Within 30 Days of Repair

The overall cumulative 30-day postoperative readmission rate was 9.98% per 30 person-days. As with other complications, the readmission rate within 30 days of surgery was higher in the dialysis cohort (14.0% vs. 9.0% rate per 30 person-days; $P < 0.001$). Dialysis dependency was associated with an increased risk of readmission in the 2012 to 2013 cohort but was not statistically significant (adjusted hazard ratio = 1.46, CI = 1.0.94−2.49, $P = 0.09$).

### Prematched Cohort and Revised Matching Criteria Analyses
#### Prematched Analysis
Additional analyses were conducted to assess for any differences in risk in the prematched cohort. Among the prematched cohort (403 dialysis; 22,218 nondialysis),

dialysis-dependent patients were younger, with proportionally more male individuals, minority race/ethnicity, diabetes, chronic obstructive pulmonary disease, and congestive heart failure, as well as poorer ASA classes, elevated body mass index, and laboratory abnormalities (Supplementary Table S1). Surgical procedures for hip fracture repair were similar between groups, but general anesthesia technique was more commonly used in dialysis patients (Supplementary Table S2). Following adjustment for age, sex, ASA class, chronic obstructive pulmonary disease, congestive heart failure, race, procedure type, diabetes, year of operation, anesthesia type, functional dependency, body mass index, albumin, and platelets, dialysis dependency was associated with greater risk of major postoperative complications (OR = 1.44, CI = 1.11−1.86, $P = 0.006$) PLOS >7 days (OR = 1.77, CI = 1.42−2.21, $P < 0.001$), higher in-hospital mortality (OR = 2.65, CI = 1.74−4.05, $P < 0.001$), greater risk of death within 30 days of procedure (OR = 2.03, CI = 1.48−2.80, $P < 0.001$), and readmission within 30 days of surgery (HR = 1.62, CI = 1.17−2.26, $P = 0.004$).

#### Analyses With Addition of ASA Matching Criteria
A sensitivity analysis was also performed to assess for changes in association between dialysis dependency and outcomes of interest when matching criteria included ASA class (groups 1−2 and 3−4). No statistically
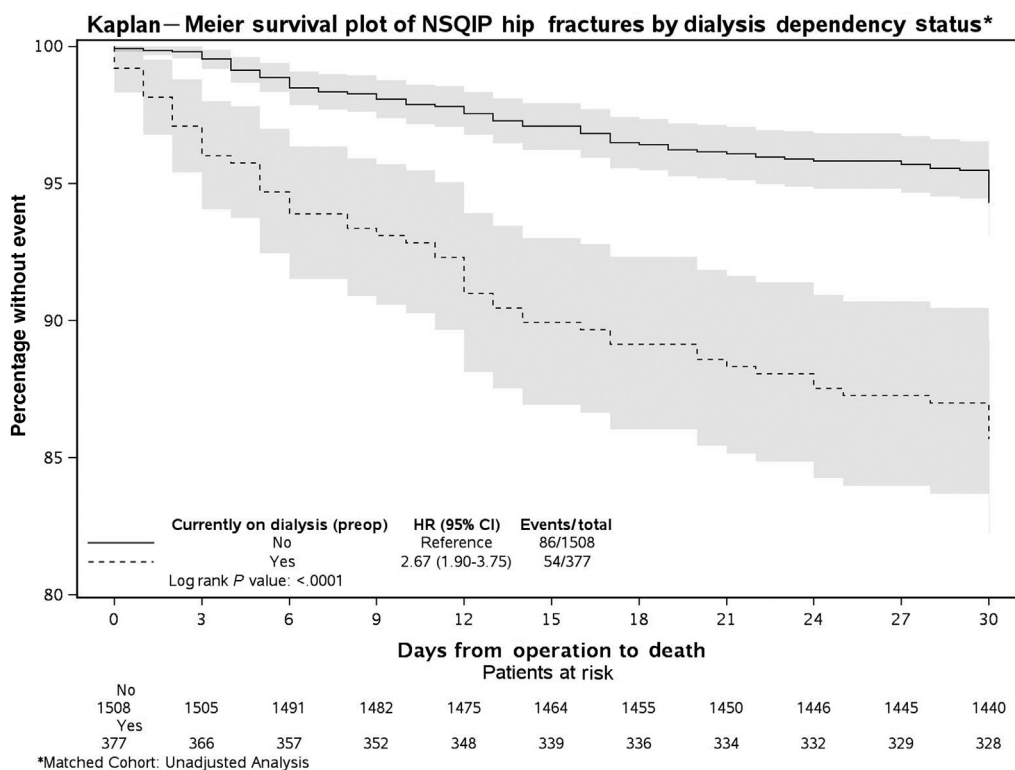


**Figure 3.** Kaplan−Meier survival curves showing 30-day survival by dialysis status in matched patients undergoing hip fracture repair (American College of Surgeons National Surgical Quality Improvement Program [NSQIP] 2010−2013). Shading represents 95% confidence intervals (CI). HR, hazard ratio; preop, preoperative.

significant differences were observed from these adjusted analyses compared to the originally matched cohort (Supplementary Table S3).

## DISCUSSION

To our knowledge, this is the first study to assess the risks of dialysis dependency independent of comorbidity in a matched cohort analysis of individuals undergoing surgical repair for hip fracture. Dialysis dependency was independently associated with an increased risk of prolonged postoperative stay death and postoperative complications within 30 days of repair. Most notably, nearly 8% of dialysis patients died before hospital discharge with a more than 3-fold adjusted risk compared with non−dialysis-dependent controls who, by design, were younger and had a higher comorbidity burden than most hip fracture patients in the general population. Given this knowledge, the morbidity inherent in dialysis dependency can be reflected in real-world discussions at the time of informed consent, quality improvement initiatives, and case-mix adjustments for bundling and quality rankings.

Similar to other studies, the findings of our study highlight the importance of acknowledging dialysis-dependent patients to be at high risk for postoperative morbidity. A study by Belmont *et al.*[32] of 44,419 patients with hip fracture in the 2008 National Trauma Data Bank (with 886 dialysis-dependent patients) showed dialysis dependency to be an important preoperative predictor of in-hospital mortality, with a considerably high risk (OR = 6.7, 95% CI = 3.6−12.7). Our study aimed to decrease the confounding of comorbid disease burden (e.g., diabetes mellitus) often found in individuals with kidney failure by matching patients on the basis of diabetes, surgical procedure, anesthesia, age, and sex. In so doing, we too found an overall rate of in-hospital deaths of 3% but nearly half the risk attributed to dialysis dependency in comparison to that reported by Belmont *et al.* (adjusted OR = 3.13, CI = 1.72−5.70; unadjusted OR = 4.6, CI = 2.67−7.82).

Finding meaningful recommendations to improve care may be challenging. A recent study conducted by Ponnusamy *et al.*[33] examined 1251 dialysis-dependent and more than 2 million non−dialysis-dependent patients undergoing primary total hip arthroplasty, primarily for osteoarthritis, from 2000 to 2009 in the National Inpatient Sample. Even for this elective procedure, inpatient mortality rates were higher in those on dialysis compared with the nondialysis group (1.88% vs. 0.13%; $P < 0.0001$); the authors concluded that "caution should be exercised in recommending arthroplasty" for dialysis patients. Hip fractures occur in a more acute setting, however, with increased morbidity and limited to no opportunity to delay surgical intervention. Le Manach *et al.*[34] supported considering different risks of death by procedure type. Among 319,804 patients undergoing hip fracture repair in the French National Discharge Database, a higher risk of in-hospital mortality after hip fracture surgery was found compared with that in a cohort undergoing elective total hip replacement (3.42% vs. 0.18%; n = 371,191). The overall relative risk of death was 5.88 (95% CI = 5.26−6.58, $P < 0.001$) for patients after hip fracture surgery in their smaller matched population analyses. Hence, hip fracture represents a procedure with increased morbidity and mortality for which intensively targeted efforts to improve postoperative outcomes are needed.

The lack of ability to select which patients undergo hip fracture repair places surgeons and medical providers in a difficult position. Belmont *et al.*[32] noted that a procedure delay of more than 2 days was associated with increased complications. Recent efforts to validate frailty risk indices and to incorporate preoperative frailty screening with multidisciplinary teams have shown promise for optimizing 30-day mortality rates in other surgical procedures.[35−37] Notably, the presence of kidney failure contributes substantial weight to frailty risk analysis indices and is an unmodifiable risk. Among dialysis-dependent patients, Sakabe *et al.*[21] found prefracture ambulation status to be the only significant predictor of life expectancy after femoral neck fractures in hemodialysis patients. However, the dialysis-dependent patients who survive to hospital discharge then are more likely to require outpatient rehabilitation, which may delay discharge and prolong hospital stays if not adequately planned.[21] These focus areas represent avenues to pursue additional quality improvement investigations for hip fracture repair.

Our study has some limitations. Although the NSQIP database represents several institutions across the United States, allowing for generalizability of study findings in addition to data reliability given data collection by well-trained nurses and staff, this database has limitations for the purpose of our investigations. These include but are not limited to the following: (i) a fixed number of predefined and specified variables collected that limit potential analyses; (ii) missing laboratory data that likely reflect variability in clinical practice; (iii) lack of data on facility-level variation (e.g., teaching/nonteaching, academic/community; size); and (iv) fracture complexity, all of which could lead to unanticipated bias. In addition, dialysis dependency may not adequately represent underlying differences in end-stage renal disease and its treatment (peritoneal vs. hemodialysis) modalities. Moreover, information is limited regarding kidney failure−relevant bone mineral

metabolism laboratory parameters, acute kidney injury—associated dialysis dependency, or preoperative timing of dialysis treatment relative to the surgical procedure. Additional studies examining differences in these areas should be further explored.

In conclusion, dialysis dependency is independently associated with an increased risk of death and postoperative complications after hip fracture repair. However, the application of these data outside of the hip fracture population to other elective procedures requires further study. Because models for reimbursement of joint replacement and other common surgical procedures change over time,[38] the incentives for outcome improvement of quality measures and cost reduction will increase. Dialysis-dependent patients represent a high-risk group that will benefit from thoughtful, targeted efforts to reduce postoperative death and complications after hip fracture.

## DISCLOSURE

All the authors declared no competing interests.

## ACKNOWLEDGMENTS

## SUPPLEMENTARY MATERIAL

**Table S1.** Baseline characteristics and laboratory tests in "Prematched" dialysis-dependent and nondialysis patients undergoing hip fracture repair (NSQIP 2010-2013).
**Table S2.** Hip fracture repair, hospital stay and postoperative complications in "Prematched" dialysis-dependent and nondialysis patients undergoing hip fracture repair (NSQIP 2010-2013).
**Table S3.** Postoperative outcomes and death by matching criteria in dialysis-dependent and nondialysis patients undergoing hip fracture repair (NSQIP 2010-2013).

Supplementary information is linked to the online version of the paper at www.kireports.org.

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