Original Article

Increased Risk of Perioperative Complications in Dialysis Patients Following Rotator Cuff Repairs and Knee Arthroscopy

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Purpose: To determine the effects of dialysis on postoperative and perioperative complications following rotator cuff repair (RCR) and knee arthroscopy (KA). **Methods:** The National Surgical Quality Improvement Program (NSQIP) was queried from 2006 to 2018. Groups were matched for age, sex, body mass index, smoking status, preoperative functional status, and the American Society of Anesthesiologists (ASA) status. Chi-squared tests and Fisher's exact tests were used to analyze the comorbidities. Differences in occurrences of postoperative adverse events (AE), mortality within 30 days, reoperations with 30 days, extended hospital stay ($\geq$2 days), and readmissions within 30 days were analyzed using the Mantel-Haenszel test. Sign tests were used to evaluate differences in operative time, as well as length of hospital stay. **Results:** Dialysis patients in both the RCR and KA groups had greater odds of experiencing any AE (OR: 6.33 and 7.46, P value: .031 and <.001, respectively) and readmission within 30 days (OR: 10.5 and 4.1, P value: .015 and .014, respectively). They also had significantly greater operating times (P = .049 for both). Dialysis patients undergoing KA had greater odds of staying in the hospital $\geq$2 days (OR: 10, P = <.001) and being reoperated on within 30 days (OR: 3.78, P = .033). The total hospital stay was significantly greater for dialysis patients in the KA group (P < .001) but not in the RCR group (P = .088). None of the individual AE's significantly differed between the dialysis and non-dialysis patients in the RCR cohort; however, dialysis patients in the KA cohort had greater incidences of three AE's. **Conclusions:** This study identified significantly worse short-term complication rates in dialysis patients undergoing RCR and KA. Careful preoperative evaluation and postoperative surveillance are warranted in this high-risk patient group. Patients should be counseled appropriately on the increased complication risks associated with RCR and KA surgeries. **Level of Evidence:** Level III, retrospective cohort study.

Introduction

With more than 468,000 Americans undergoing dialysis as of 2019,[1] the prevalence of chronic kidney disease and those requiring dialysis is expected to grow significantly as the prevalence of diabetes in America is predicted to approach 48.3 million by 2050.[2] With a greater prevalence of end-stage renal disease, more hemodialysis-dependent patients are expected to undergo various surgical procedures, including rotator cuff repair (RCR) and knee arthroscopy (KA). Understanding the potential risks for adverse events that dialysis patients may face after such surgeries is pertinent to ensuring proper patient education and case management.

Rotator cuff disease is believed to result both from acute injury and progressive degeneration or wear and tear of the tendon tissue.[3] RCR surgery is commonplace and performed over 400,000 times annually,[4] with restoration of function and high patient satisfaction rates.[5,6] Meanwhile, KA is used to treat a variety of knee issues and injuries. Knee arthroscopies are one of the most common arthroscopies, with orthopaedic surgery residents each performing on average 185 knee arthroscopies in 2013.[7] Failure and postoperative complications following these surgeries can occur for a variety of reasons, including impaired healing as a

consequence of health conditions, such as renal dysfunction. Bohensky et al. found that chronic kidney disease was a risk factor for adverse outcomes following elective knee arthroscopies.[8] Additionally, a retrospective study by Wu et al. demonstrated that the systemic effects in hemodialysis-dependent patients yielded inferior results in shoulder function and pain following RCR compared to patients without hemodialysis.[9]

Although a life-preserving treatment, hemodialysis has numerous side effects with prior studies showing increased adverse events, readmissions, and reoperation and mortality rates.[10,11] Chronic hemodialysis is a known significant risk factor for weakening tendon structures,[12] attributed to elevated serum levels of β2 microglobulin (β2M) that can no longer be filtered by failing kidneys.[13] β2M indiscriminately deposits in the musculoskeletal system and is correlated with structural alterations to rotator cuff tendons, in turn, increasing the risk of tearing and deficiency in subsequent healing.[14,15]

Changes in tendon structure and altered postoperative healing environments in patients with failing kidneys necessitate further observation of operative outcomes and complications in hemodialysis-dependent patients.[16-18] Additionally, with the expected increase in patients with chronic kidney disease, it is vital to understand what risk dialysis patients face for developing perioperative and postoperative complications. The purpose of this study was to determine the effects of dialysis on postoperative and perioperative complications following RCR and KA. We hypothesize that dialysis-dependent patients will experience greater complication rates when compared to a matched non-dialysis cohort.

Methods

This is a retrospective matched case-control study of postoperative outcomes following RCR and KA procedures for patients who were on dialysis at the time of the procedure. The National Surgical Quality Improvement Program (NSQIP) was queried from 2006 to 2018 using CPT codes for either open or arthroscopic RCR (23410, 23412, 23420, and 29827), as well as knee arthroscopic repair procedures (29880, 29881, 29879, 29874, 29875, 29876, 29873, 29877, 29882, 29883, and 29884). As of 2017, the NSQIP dataset contained data from 708 hospitals. Each individual site has a trained clinical reviewer that collects data on over 150 variables, including 30-day postoperative outcomes for patients. This process uses a variety of methods, including medical chart reviews. Overall, there was a total of 50,420 RCR procedures conducted with the above CPT codes, and there were a total of 120,793 knee arthroscopy procedures conducted with the above CPT codes.

The NSQIP database defines a dialysis-dependent patient as a patient requiring peritoneal dialysis,

hemodialysis, hemofiltration, hemodiafiltration, or ultrafiltration within 2 weeks prior to the RCR procedure. Hemodialysis makes up ∼90% of all dialysis patients, so it can be assumed that the majority of patients included in this study received hemodialysis.[19] The following demographic data were obtained from the database: age, sex, body mass index (BMI), smoking status within 1 year of operation, functional status, and American Society of Anesthesiologists (ASA) Classification score. Age was categorized as <40, 40-49, 50-59, 60-69, 70-79, 80-89, and ≥90 years old. BMI was separated into the following categories: normal (<25), overweight (25-29.99), obese (30-39.99), and morbidly obese (≥40). Finally, function status was categorized as "Independent" and "Partially/Totally Dependent".

Postoperative Outcomes

Variables corresponding to postoperative 30-day complications were organized into one variable called "Any Adverse Event" (AAE). The following complications were placed into this AAE category: surgical site infection, wound dehiscence, pneumonia, unplanned intubation, pulmonary embolism, ventilation for >48 hours after procedure, renal failure, urinary tract infection, cerebrovascular accident (stroke), cardiac arrest, myocardial infarction, bleeding requiring transfusion, deep vein thrombosis, sepsis, and septic shock. These complications were also analyzed separately. Occurrences of reoperations, extended hospital stay (≥2 days), and readmission within 30 days of a procedure were individually analyzed. Furthermore, differences in operative time and length of stay between cases and controls were analyzed.

Statistics

For both the RCR group and the KA group, the cases (dialysis-dependent patients) and the controls (non-dialysis-dependent patients) were matched using coarsened exact matching (CEM). In an effort to mitigate confounding factors, the groups in this study were matched for age, sex, BMI, smoking status, functional status, and ASA score. Although there are several other variables for which the groups could have been matched, we considered these to be the most significant potential confounders of the information available in the database, and previous studies have matched cohorts on the basis of similar criteria.[11,20,21] The RCR group was matched using a target ratio of 1 case to 5 controls, and the KA group was matched using a target ratio of 1 case to 2 controls. These ratios were used because there were available data and because of the increased power.[22] CEM "coarsens" continuous (age) matched variables and then uses an exact matching algorithm with the target variables. This method is less sensitive to measurement error (random and systemic error), meets the congruence principle, balances

Table 1. Demographic Data for the Rotator Cuff Repair Group and the Knee Arthroscopy Group

| | Rotator Cuff Repair Group | | | Knee Arthroscopy Group | | |
| | Non-Dialysis Patients $n = 277$ | Dialysis Patients (Cases) $n = 58$ | | Non-Dialysis Patients $n = 264$ | Dialysis Patients (Cases) $n = 134$ | |
Demographics	Percentage (%)	Percentage (%)	P Value	Percentage (%)	Percentage (%)	P Value
Age − Average years	58.2	61		57.52	57.51	
≤40	1.8	1.7	.998	8.7	9.0	1.00
41-50	12.3	13.8		18.6	18.7	
51-60	30.7	29.3		26.5	26.1	
61-70	33.6	32.8		30.3	30.6	
71-80	19.1	19		11.4	11.2	
>80	2.5	3.4		4.5	4.5	
Sex						
Male	30	29.3	.921	60.2	59.7	.919
Female	70	70.7		39.8	40.3	
BMI − average BMI	32.1	32.1		32.4	31.4	
Normal (<25)	7.6	8.6	.996	20.1	20.9	.998
Overweight (25-29.99)	37.2	34.5		25.8	25.4	
Obese (30-39.99)	42.6	44.8		36	35.8	
Morbidly obese (≥40)	12.6	12.1		18.2	17.9	
Smoking status						
No	96	94.8	.717	81.8	81.3	.908
Yes	4	5.2		18.2	18.7	
Functional status						
Independent	93.1	89.7	.407	92.4	91.8	.824
Partially/totally dependent	6.9	10.3		7.6	8.2	
ASA Classification						
1. No disturbance	1.8	1.7	.998	0	0	.992
2. Mild disturbance	21.7	20.7		17.4	17.2	
3. Severe disturbance	53.8	55.2		48.9	48.5	
4. Life threatening	22.7	22.4		33.7	34.3	
5. Moribund	0	0		0	0	

BMI, body mass index.

nonlinearities, eliminates the need for a separate procedure for estimation, and is considered computationally efficient.[21,23-25] CEM is a monotonic imbalance bounding method, which means that adjusting the balance in one factor does not affect another factor.[26] The exact matching algorithm also means that there is no further need for risk adjustment with respect to the matched variables.[23,25]

To compare proportions of complications between cases and controls, Mantel-Haenszel tests were performed. The Mantel-Haenszel test is noted in the literature as an appropriate test to compare proportions between matched groups with multiple controls per case.[27-29] For the numerical values (operative time and length of stay), Sign tests were used due to non-normal distributions, as well as the case control-matched design. However, the Sign test requires a 1 to 1 design. Thus, for these numerical variables, the values for each set of controls were averaged, so that there was a 1 to 1 matched dataset. Mean values and P values were reported for these tests.

The demographic variables were compared between cases and controls for both the RCR and KA groups to ensure they were both matched appropriately. For the specific purpose of ensuring the groups were matched, χ^2-tests and Fisher's exact tests were used. The Fisher's exact test was used as an alternative for comparisons that did not meet the χ^2 assumptions. The RCR case group and the KA case group were also compared on the variables discussed above (demographic variables, complications, adverse events, operative time, and length of stay). For this analysis, χ^2 tests and Fisher's exact tests were performed. Mann-Whitney U-tests were used for the numerical variables due a non-normal distribution. Mean values as well P values were reported for these tests. Results were significant if $P < 0.05$.

Results

In the NSQIP dataset, there were a total of 60 RCRs performed on dialysis-dependent patients. Two of these patients were not included in the analysis due to lack of a match in the control database. The CEM matching algorithm resulted in a control population of 277 RCR patients who were not dialysis-dependent. Five of the 58 patients did not have a total of 5 matches due to unavailability: 3 patients had 3 matches, 1 patient had 2 matches, and the last patient had only 1 match. These

Table 2. Rates of Complications and Outcomes Between Dialysis and Non-Dialysis Patients Undergoing Rotator Cuff Repair

Complications	Non-dialysis Patients $n = 277$ (%)	Dialysis Patients $n = 58$ (%)	P Value	Odds Ratio	Confidence Interval
Any Adverse Event	1.1	6.9	**.031**	6.33	1.24 - 32.26
Superficial infection	0	1.7	.37		
Deep infection	0	0	1		
Wound dehiscence	0	0	1		
Pneumonia	0	1.7	.56		
Unplanned intubation	.4	0	.65		
Pulmonary embolism	0	0	1		
Ventilation for >48 hours	0	0	1		
Progressive renal insufficiency	0	0	1		
Renal failure	0	0	1		
Urinary tract infection	0	0	1		
Cerebrovascular accident (stroke)	0	0	1		
Cardiac arrest	0	0	1		
Myocardial infarction	.7	0	.48		
Bleeding requiring transfusion	.4	1.7	.88		
Deep vein thrombosis	0	0	1		
Sepsis	0	1.7	.37		
Septic shock	0	0	1		
Mortality within 30 days	0	0	1		
Extended hospital stay (≥2 days)	4.3	12.1	.072		
Reoperations within 30 Days	.4	0	.65		
Readmission within 30 Days	1.2	9.4	**.015**	10.5	1.95-56.55
Numerical variables					
Operating Time (Av. Min. ± Std. Dev.)	81.53 ± 16.78	78.48 ± 40.63	**.049**		
Total Hospital Stay (Av. Days ± Std. Dev.)	0.32 ± 0.73	1.05 ± 3.79	.088		

Bolded values indicate significant difference. Av., Average; Min., minutes; Std. Dev., standard deviation.

patients were still included because they matched to at least one control. For the KA patients, there were 141 KA patients that underwent dialysis within the 2 weeks prior to their procedure. Using the same CEM matching algorithm, we found 134 cases with viable matches. This resulted in a control population of 264 because 4 cases only had one matched control. Because of the limited number of cases meeting criteria for inclusion in this study, it was decided that both open and arthroscopic procedures would be treated as one group.

Because of the matching algorithm, there were no significant differences in the shoulder arthroscopy group between cases and controls for the demographic variables (Table 1). For age, the majority of patients were between 41 and 80 years of age. There was a higher proportion of female patients in both groups (70% female vs. 30% male). For BMI, the majority of patients were either overweight or obese. The vast majority of patients did not smoke in the year leading up to the procedure. For functional status, most patients were considered independent, with only 7% of the non-dialysis patients and 10% of dialysis patients considered to be partially or totally dependent. Finally, for the ASA Classification, most patients were ASA Class 3, and there were no significant differences in the ASA Classification between the two groups.

For the KA patients, the majority of patients were also between 41 and 80 years old (Table 1). There was a higher proportion of male patients than female patients in the KA case-control matches (60% male vs. 40% females). Again, for BMI, the majority of the KA group was overweight or obese. About 18% of the KA patients were smokers. The majority of patients were considered to be independent in the Functional Status variable. For the ASA Classification, most patients were ASA Class 3, severe disturbance (49%) and ASA class 4, life threatening (34%). Because of the matching algorithm, there was no significant difference between any of these demographic variables for the dialysis and non-dialysis KA patients.

Table 2 compares the proportions of complications and adverse events between dialysis-dependent patients ($n = 58$) and the matched control group ($n = 277$) within the shoulder arthroscopy patients. When comparing the cases and controls, a significant increase in AAE was found, with dialysis patients experiencing a higher complication rate (6.9% vs. 1.1%, OR: 6.33, $P = .031$). Using Sign tests to compare the length of hospital stay, dialysis patients experienced a longer mean hospital stay (1.05 days vs. .32 days, $P = .088$), which was not statistically significant. Postoperatively, dialysis patients also experienced a higher

Table 3. Rates of Complications and Outcomes Between Dialysis and Non-Dialysis Patients Undergoing Knee Arthroscopy

Complications	Non-dialysis Patients $n = 264$ (%)	Dialysis Patients $n = 134$ (%)	P-value	Odds Ratio	Confidence Interval
Any adverse event	3.4	19.4	**<.001**	7.46	2.88-19.30
Superficial infection	0	0	1		
Deep infection	1.1	2.2	.665		
Wound dehiscence	0	0	1		
Pneumonia	.8	.7	1		
Unplanned intubation	0	.7	.724		
Pulmonary embolism	0	0	1		
Ventilation for >48 hours	0	3	**.022**	*	*
Progressive renal insufficiency	0	0	1		
Renal failure	.4	0	.479		
Urinary tract infection	0	.7	.724		
Cerebrovascular accident (stroke)	0	.7	.724		
Cardiac arrest	0	1.5	.211		
Myocardial infarction	0	.7	.724		
Bleeding requiring transfusion	.4	8.2	**<.001**	21.5	$2.77 - 166.86$
Deep vein thrombosis	0	0	1		
Sepsis	1.5	10.4	**<.001**	7.71	$1.96 - 30.36$
Septic shock	.4	2.2	.216		
Mortality within 30 Days	2.2	0	.066		
Extended hospital stay ($\geq$2 days)	10.2	39.6	**<.001**	10	$4.46 - 22.39$
Reoperations within 30 Days	1.6	8.3	**.033**	3.78	$1.15 - 12.39$
Readmission within 30 Days	1.2	9.4	**.014**	4.1	$1.40 - 12.02$
Numerical variables					
Operating time (Av. Min. $\pm$ Std. Dev.)	32.34 ± 12.44	36.15 ± 17	**.049**		
Total Hospital Stay (Av. Days $\pm$ Std. Dev.)	$.71 \pm 2.06$	4.56 ± 7.3	**<.001**		

Av., Average; Min., minutes; Std. Dev., standard deviation. **Bolded** values are significant.

*Odds Ratio not computed due to 0 value in the denominator.

proportion of extended stays (12.1% vs. 4.3%, $P =$ .072); however, these results were also not statistically significant. Dialysis patients were readmitted at a significantly higher rate within 30 days (9.4% vs. .8%, OR: 10.5, $P = .015$). Operating time was found to be lower in the dialysis group, but this was just within statistical significance ($P = .049$). There were no significant differences between the two groups in regard to reoperations, mortality, and surgical site deep infections within 30 days ($P = .65$, $P = 1$, and $P = 1$, respectively). For the 5 RCR-dialysis patients that were readmitted, one was an open procedure, while the rest were arthroscopic patients. One patient had a diagnosis of "Other affections of shoulder region", another had a diagnosis of adhesive capsulitis, and two had partial or complete rotator cuff tears; the last one did not have a diagnosis listed.

Table 3 compares dialysis ($n = 134$) and non-dialysis ($n = 264$) patients who underwent KA. Comparing these two groups, there was a significant difference in terms of the AAE variable, with the dialysis patients experiencing a much higher percentage of adverse events (19.4% vs. 3.4%, OR: 7.46; $P < .001$). The Sign test showed a significantly greater length of total hospital stay in the dialysis patient group (4.56 days vs. 0.71 days, $P < .001$). Similarly, there was a higher

proportion of extended stays among the dialysis group (39.6% vs. 10.2%, OR = 10, $P < .001$). KA patients who underwent dialysis also experienced a higher number of readmissions (9.4% vs. 1.2%, OR = 4.1; $P = .014$) and reoperations (8.3% vs. 1.6%, OR = 3.78; $P = .033$). Furthermore, 2.2% of the dialysis group died within 30 days of the procedure, while 0% of the non-dialysis group died. This difference in mortality approached statistical significance with a P value of .066. Finally, the dialysis patient group had a higher average operating time; however, this was just within statistical significance ($P = .049$). There was no difference in surgical site deep infection between the dialysis and the non-dialysis group ($P = .665$). For the 14 knee arthroscopy-dialysis patients who were readmitted, 7 of them did not have a listed diagnosis. One of the other patients had hemarthrosis of the lower leg, another had effusion of knee joint, another had a tear of the meniscus, one had unspecified septicemia, another had an unspecified disorder of the knee, and finally, two patients had pyogenic arthritis.

Table 4 compares the demographic information between the dialysis patients who underwent a KA versus RCR. The unmatched subjects that were removed in the case-control analyses were included in this analysis. There were 141 KA patients and 60 RCR patients. There

Table 4. Comparing the Demographics for the Dialysis Patients in the Knee Arthroscopy Group Versus the Dialysis Patients in the Shoulder Arthroscopy Rotator Cuff Repair Group

Demographics	Knee Arthroscopy Patients n = 141 Percentage (%)	Shoulder Arthroscopy Patients n = 60 Percentage (%)	P Value
Age − Average Years	57.4	61.5	
≤40	9.2	1.7	.144
41-50	19.1	13.3	
51-60	26.2	28.3	
61-70	29.8	31.7	
71-80	10.6	21.7	
>80	5.0	3.3	
Sex*			
Male	59.6	68.3	.241
Female	40.4	31.7	
BMI − Average BMI	31.2	32.1	
Normal (<25)	22.0	8.3	**.049**
Overweight (25-29.99)	25.5	35.0	
Obese (30-39.99)	34.8	45.0	
Morbidly Obese (≥40)	17.7	11.7	
Smoking Status			
No	80.9	95.0	**.01**
Yes	19.1	5.0	
Functional status*			
Independent	90.1	86.7	.48
Partially/Totally Dependent	9.9	13.3	
ASA Classification			
1 - No Disturbance	0	1.7	.225
2 - Mild Disturbance	16.3	20.0	
3 - Severe Disturbance	46.1	53.3	
4 - Life Threatening	36.9	25.0	
5 - Moribund	.7	0	

BMI, body mass index. **Bolded** values are significant.

*Some subjects were missing data for functional status.

was no significant difference in the demographic information except for BMI and smoking status ($P = .049$ and $P = .01$, respectively). KA patients had a higher proportion of smokers (19.1%) compared to shoulder arthroscopy patients (5%). Shoulder arthroscopy patients had a higher portion of overweight and obese patients compared to KA patients.

Table 5 compares the outcome data between dialysis patients who underwent a KA and dialysis patients who underwent a shoulder arthroscopy. KA patients had a higher incidence of adverse events (21.3% vs. 6.7%, OR = 3.78; $P = .011$). KA patients also had a higher proportion of extended hospital stays (41.1% vs. 15%, OR = 3.96; $P < .001$). Furthermore, KA patients experienced a higher number of reoperations compared to shoulder arthroscopy patients (7.9% vs. 0%; $P = .034$). Dialysis patients in the KA cohort had significantly shorter operating times, but significantly longer hospital stays, compared to dialysis patients in the RCR cohort ($P < .001$ and $P = .003$, respectively).

Discussion

Overall, this study found that there was a higher proportion of adverse events in the dialysis group (cases) for both the rotator cuff repair cohort, as well as the knee arthroscopy cohort. Although several previous studies have investigated dialysis versus non-dialysis patients undergoing various orthopaedic procedures, this study analyzed complication rates in the dialysis population undergoing RCR or knee arthroscopies.[9-11,20,21,30-33] In this study, the experimental group consisting of dialysis patients undergoing both RCR and KA were compared to a matched control group of non-dialysis patients matched for key demographic factors and comorbidities. There were no significant differences in age, sex, BMI, smoking status, functional status, or ASA classification between experimental and control groups, further ensuring that differences in outcomes between groups are due to the independent effect of dialysis. The results of this study show that dialysis patients undergoing RCRs fared worse than their non-dialysis matched controls in terms of experiencing any perioperative adverse event and being readmitted more frequently within 30 days of surgery. There were no differences between the RCR groups in regard to their length of stay, the frequency of reoperation, or the mortality rate. The dialysis patients undergoing knee arthroscopies also fared significantly

Table 5. Rates of Complications and Outcomes Between Dialysis Patients Undergoing Knee Arthroscopy and Dialysis Patients Undergoing Shoulder Arthroscopy

Complications	Knee Patients $n = 141$ (%)	Shoulder Patients $n = 60$ (%)	P Value	Odds Ratio	Confidence Interval
Any adverse event	21.3	6.7	**.011**	**3.78**	1.27-11.27
Superficial infection	0	1.7	.30		
Deep infection	2.1	0	.56		
Wound dehiscence	0	0	1		
Pneumonia	.7	1.7	.51		
Unplanned intubation	.7	0	.71		
Pulmonary embolism	0	0	1		
Ventilation for >48 hours	2.8	0	.32		
Progressive renal insufficiency	0	0	1		
Renal failure	0	0	1		
Urinary tract infection	.7	0	1		
Cerebrovascular accident (stroke)	.7	0	1		
Cardiac arrest	1.4	0	1		
Myocardial infarction	.7	0	1		
Bleeding requiring transfusion	9.9	1.7	**.043**	**6.5**	.84-50.63
Deep vein thrombosis	0	0	1		
Sepsis	9.9	1.7	**.043**	**6.5**	.84-50.63
Septic shock	2.8	0	.32		
Mortality within 30 Days	0	0	1		
Extended hospital stay (≥2 days)	41.1	15.0	**<.001**	**3.96**	1.81-8.67
Reoperations within 30 days	7.9	0	**.034**	*	*
Readmission within 30 days	9.4	9.1	.94		
Operating Time (Av. Min. ± Std. Dev.)	35.8 ± 17	77.64 ± 40.3	**<.001**		
Total Hospital Stay (Av. Days ± Std. Dev.)	4.14 ± 11.5	1.12 ± 3.75	**.003**		

Av., Average; Min., minutes; Std. Dev., standard deviation. **Bolded** values indicate significant difference.

*Odds Ratio not calculated due to 0 in the denominator

worse than the patients not undergoing dialysis, with the dialysis patients experiencing an increased risk of being readmitted within 30 days, being reoperated on within 30 days, staying in the hospital for longer periods, experiencing a longer operating time, and developing an adverse event. Because the dialysis and control groups were matched by age, sex, BMI, smoking status, functional status, and ASA score, these results suggest that dialysis is a significant independent risk factor for increased 30-day complication and readmission rates.

This study is also impactful in regard to its efforts to directly compare the demographic characteristics and postoperative complication rates of dialysis patients undergoing RCR to dialysis patients undergoing KA. The results showed that dialysis patients were significantly more likely to suffer a complication, require a transfusion, and become septic, all within 30 days of surgery (Table 5). KA patients were also significantly more likely to experience extended hospital stays, have longer total hospital stays, undergo reoperation within 30 days, and experience longer operating times. The underlying reasons for unfavorable morbidity profile of KA compared to RCR in dialysis patients is uncertain and likely multifactorial, and will require further study. A demographic and comorbidity comparison between dialysis patients undergoing RCR and KA showed that

patients undergoing KA were significantly more likely to be smokers, which many contribute slightly to the unfavorable comorbidity profile of KA in the study.

A recent study investigated RCR in dialysis patients compared to non-dialysis patients using institutional data from 42 patients.[9] Unlike our study, this study focused solely on functional outcomes and did not include postoperative complications or length-of-stay data. The study found that dialysis patients experienced significantly worse functional outcomes at a mean follow-up of 21 months when assessed using SST, ASES, UCLA, and visual analog scale shoulder scores. However, both groups had significantly improved scores when compared to baseline, preoperative scores. These results indicate that dialysis patients may still benefit from RCR surgery in terms of pain relief and function, but the benefit is not as great as for non-dialysis patients. Notably, our study showed no difference between groups in regard to the duration of surgery, frequency of reoperation, or mortality, again highlighting that RCR can still be a safe and effective procedure in the dialysis population when proper precautions are taken.

A study by Bohensky et al. found that chronic kidney disease is a risk factor for experiencing adverse events in patients undergoing knee arthroscopies.[8] Similarly, renal failure was found to be an independent risk factor

for readmission after a KA.[34] Neither of the afore-mentioned studies focused solely on dialysis patients receiving knee arthroscopies, with any literature analyzing this subgroup of KA patients appearing to be sparse or nonexistent. Of great concern is the increased risk of adverse events, readmissions, and reoperations for dialysis patients who receive a KA. Specifically, our results showed an increased risk of developing sepsis, being on a ventilation system for >48 hours, and undergoing a transfusion due to bleeding. The risk of mortality can increase by up to 9-fold in dialysis patients with sepsis compared to dialysis patients without sepsis, highlighting the gravity of our results, indicating that dialysis patients receiving a KA were at an increased risk for developing sepsis.[35] Additionally, postoperative blood transfusions are associated with increased mortality and complications, even further reiterating the adverse implications of the dialysis patients being at a higher risk for receiving a blood transfusion in our KA results.[36] Physicians should give special consideration to dialysis patients receiving knee arthroscopies and make sure to inform their dialysis patients on the increased risk of adverse outcomes.

The results of this study are congruent with previous studies evaluating outcomes in dialysis patients undergoing other orthopaedic surgical procedures. A recent study performed by Cancienne et al. investigated total shoulder arthroplasty in dialysis patients compared to non-dialysis patients using an insurance database and found that dialysis patients experienced significantly increased rates of in-hospital death, emergency department visits, hospital admissions, and infections within 1 year of shoulder arthroplasty in comparison to non-dialysis dependent patients.[10] This study also stratified patients by modality of dialysis received and found that hemodialysis patients fared significantly worse than peritoneal dialysis patients for many of the outcomes measured. Several other studies have investigated dialysis patients undergoing other orthopaedic procedures, including hip and knee arthroplasty, geriatric hip fracture procedures, and elective spine surgery, with all studies showing an increased risk of postoperative complications in dialysis patients compared to non-dialysis patients.[11,20,21,30-33]

The pathophysiological mechanisms by which dialysis may lead to postoperative complications is not entirely understood and is most likely multifactorial. In this study, almost all of the postoperative complications involved infectious processes (superficial infection, pneumonia, and sepsis). Patients on hemodialysis require frequent vascular access to receive therapy and have demonstrated high rates of bacteremia and hospitalizations in previous studies.[37-39] Recent evidence also shows that vitamin D may play an important role in modulation of the immune and inflammatory systems, with some studies showing that low levels of vitamin D, such as those found in patients with chronic kidney disease, are associated with both increased risk of infection and unfavorable outcomes of several infectious disease processes.[40-44] This evidence may at least partially explain the results of this study in regard to the increased rate of adverse events and the increased readmission rate.

Despite dialysis patients having significantly worse risk of complication after KA compared to RCR surgery, physicians must consider the increased risk of adverse outcomes in both subgroups by taking extra precautions to address any preventable postoperative complications and by educating their patients on the matter. Optimizing dialysis patients in the perioperative setting may require special considerations. Preoperatively, patients should be screened for cardiovascular disease and should be assessed in regard to volume status, electrolyte levels, hematocrit, and blood glucose.[45] Additionally, patients can benefit from receiving dialysis within 24 hours of surgery.[46] Intraoperatively, fluid status should be monitored vigilantly. Postoperatively, patients should again be closely monitored for volume status, electrolyte balance, urea and creatinine levels, and blood glucose levels.[45] There is currently no evidence regarding the optimal time to start postoperative dialysis, but, in general, patients should try to maintain their preoperative dialysis routine as closely as possible.[45] Some studies demonstrated that the use of irrigation solution in shoulder arthroscopy can result in fluid extravasation, which can be exacerbated by renal disturbances.[47,48]

This study provides valuable information that orthopaedic surgeons can translate into clinical practice. Future studies should analyze longer-term complications and functional outcomes using larger sample sizes and should also stratify cases based on open versus arthroscopic repair.

Limitations

There are potential limitations to this study. One limitation is that procedures were not stratified on the basis of open versus arthroscopic RCR procedures. Another limitation to this study is that dialysis patients were not stratified by the type of dialysis that they received either (hemodialysis or peritoneal dialysis) prior to surgery because the NSQIP database does not specify the type of dialysis that patients receive. We do not have information regarding sidedness of surgery with respect to a patient's AV fistula, and we are unable to make specific recommendations for risk mitigation. Finally, the presence of confounding variables is always a possibility.

Conclusion

This study identified significantly worse short-term complication rates in dialysis patients undergoing RCR and KA. Careful preoperative evaluation and

postoperative surveillance are warranted in this high-risk patient group. Patients should be counseled appropriately on the increased complication risks associated with RCR and KA surgeries.

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