Dialysis dependence and modality impact complication rates after shoulder arthroplasty

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Background: The goals of the study were to determine (1) the incidence of dialysis patients undergoing shoulder arthroplasty (SA), (2) the association of dialysis modality with complications after SA, and (3) the association of dialysis dependence with death in patients undergoing SA and nonsurgical dialysis-dependent controls.

Methods: Using an insurance database, we identified dialysis-dependent patients undergoing SA and compared them with a matched control cohort without dialysis use. We performed an analysis comparing patients using peritoneal dialysis (PD), patients using hemodialysis (HD), matched non–dialysis-dependent controls, and matched PD and HD nonsurgical patients. Complications including in-hospital death, emergency department visits, hospital readmission, infection, and revision surgery were assessed.

Results: The incidence of SA in dialysis patients has significantly increased. Compared with controls, dialysis-dependent patients had increased rates of in-hospital death (odds ratio [OR], 7.60; $P < .0001$), emergency department visits (OR, 4.16; $P < .0001$), hospital admission (OR, 1.63; $P < .0001$), and infection within 1 year (OR, 1.90; $P = .009$). Compared with patients receiving HD, PD patients had lower rates of death (OR, 0.40; $P = .008$), hospital readmission (OR, 0.43; $P = .047$), and revision surgery (OR, 0.23; $P = .037$). as well as a lower incidence of infection (OR, 0.30; $P = .018$). Compared with controls, PD patients had similar rates of most complications. Compared with nonsurgical dialysis-dependent patients, the SA procedure itself was not associated with an increased mortality rate.

Conclusions: Although dialysis represents a significant independent risk factor for complications after SA, this risk is highly influenced by the type of dialysis.

Level of evidence: Epidemiology Study; Large Database Analysis

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The prevalence of chronic kidney disease requiring hemodialysis (HD) continues to increase worldwide, and according to the latest US Renal Data System Annual Data Report, more than 468,000 Americans are dialysis patients.[20] This number is expected to increase dramatically as the prevalence of diabetes is projected to increase to 48.3 million in 2050.[17] Although dialysis is a life-preserving treatment for patients with end-stage renal disease, there are numerous side effects that affect quality of life while receiving dialysis.[4]

Musculoskeletal pain in the dialysis-dependent patient is common and is frequently due to osteoarthritis or osteonecrosis secondary to corticosteroid use during renal failure, most commonly affecting the knee, hip, and shoulder joints.[10] The lower-extremity arthroplasty literature has reported a substantially higher cumulative incidence of total hip arthroplasty in dialysis-dependent patients compared with the general population.[1] Given the increasing frequency of dialysis-dependent patients presenting for lower-extremity arthroplasty evaluation and treatment, an abundance of literature has focused on the relationship between dialysis dependence and lower-extremity arthroplasty outcomes. This literature has established dialysis dependence as an independent risk factor for poor outcomes and significantly increased morbidity and mortality rates after total hip and knee arthroplasty.[9,14,16,18,19,23]

The number of shoulder arthroplasties performed in the United States has increased at a rate of 7% to 13% per year, which is substantially higher than the number of lower-extremity arthroplasties.[8,13] Similarly to lower-extremity joint arthroplasty, it is critical to identify patient risk factors associated with postoperative complications after shoulder arthroplasty. However, in contrast to the abundance of literature detailing the effect of dialysis on lower-extremity arthroplasty outcomes and complications, little literature has investigated whether a similar relationship exists with shoulder arthroplasty. Given the aforementioned increase in the number of dialysis-dependent patients and the continued increase in the use of shoulder arthroplasty as a reliable treatment for end-stage glenohumeral joint arthritis, it is of high clinical significance to investigate the impact of dialysis dependence on postoperative outcomes after total should arthroplasty. Therefore, the purposes of this study were to use a national insurance database to investigate (1) the cumulative incidence of shoulder arthroplasty in dialysis-dependent patients, (2) the relationship between dialysis dependence and postoperative complications after shoulder arthroplasty compared with matched controls, (3) the relationship between dialysis modality and postoperative complications after shoulder arthroplasty compared with matched controls, and (4) the relationship between mortality rates in peritoneal dialysis (PD) and HD patients undergoing shoulder arthroplasty and matched PD and HD patients not undergoing shoulder arthroplasty.

Materials and methods

Database

We performed a retrospective case-control study of outcomes after shoulder arthroplasty in dialysis-dependent patients. The PearlDiver patient records data repository (PearlDiver Technologies, West Conshohocken, PA, USA; http://www.pearldiverinc.com), an insurance-based database, was used for this study. This is a publicly available administrative database containing only deidentified information. The database contains patient records from several separate private insurers and 100% of the Medicare database with procedural volumes and patient demographic characteristics for patients with *International Classification of Diseases, Ninth Revision* (ICD-9) diagnoses and procedures or Current Procedural Terminology (CPT) codes. Given that all patients in the United States receiving dialysis qualify for Medicare, the data for this study were derived from the Medicare data set to capture the maximum number of patients. The Medicare data set in the PearlDiver database contains more than 55 million individual patient records from 2005 to 2014, and patients can be tracked across all locations of care as long as Medicare insurance is used for the encounter.

Study and control cohorts

We sought to define a study population of patients who were dialysis dependent and underwent shoulder arthroplasty. The database was first queried for all patients who underwent total shoulder arthroplasty (TSA), reverse TSA, or shoulder hemiarthroplasty using ICD-9 procedure codes 81.80, 81.81, and 81.88. Patients receiving PD who underwent shoulder arthroplasty were subsequently identified using CPT codes 49324, 49418, 90945, 90947, and 49421, in addition to ICD-9 procedural codes 54.98, S93.39, E15.92, E15.94, and E16.30, present within the 6 months before shoulder arthroplasty. Patients receiving HD were identified using CPT codes S9335, 90935, 90937, and 99512, in addition to ICD-9 procedural code 39.95, within the 6 months before shoulder arthroplasty. Because many patients receiving PD may have received HD in the past, any patients with both HD and PD codes in the 6 months before surgery were allocated to the HD group. For the first and second study objectives, this group of dialysis-dependent patients was evaluated together (both HD and PD patients combined). For the third study objective, the PD and HD patients were separated for analysis.

After application of our inclusion and exclusion criteria, a control cohort of patients who underwent shoulder arthroplasty with no prior dialysis use was created for study objective 2. This control cohort was then matched to the overall dialysis study patients in a 3:1 ratio based on age, sex, year of procedure, obesity, tobacco use, alcohol abuse, and diabetes mellitus.

For study objective 3, available HD patients were first matched to PD patients in a 1:1 ratio based on age, sex, year of procedure, obesity, tobacco use, alcohol abuse, and diabetes mellitus. Subsequently, a second control group was created for this objective, matching non–dialysis-dependent patients to PD patients in a 3:1 ratio using the same matching criteria.

Finally, for study objective 4, available HD and PD patients without a history of any shoulder arthroplasty procedure were matched to our study PD and HD cohorts in a 3:1 ratio based on age, sex, obesity, tobacco use, alcohol abuse, and diabetes mellitus, and the mortality rates were queried and compared.

To reduce the effects of transient patients such as those who might lose insurance because of an employment change or retirement in the immediate postoperative period, only patients with a minimum of 90 days of postoperative database activity were included. We then performed a query of patients in the study and control groups for basic demographic characteristics and comorbidities including age, sex, year of procedure, obesity, morbid obesity, tobacco use, alcohol abuse, diabetes mellitus, hyperlipidemia, hypertension, peripheral vascular disease, congestive heart failure, coronary artery disease, chronic lung disease, chronic liver disease, thyroid disease, and depression.

Incidence of shoulder arthroplasty

The incidence of shoulder arthroplasty in dialysis-dependent and non–dialysis-dependent patients was calculated on an annual basis from 2005 to 2014 as reported by the database. For the control group, the denominator was all active Medicare enrollees in a given year minus the number of dialysis patients.

Complications

Complications were assessed for the overall dialysis cohort, HD cohort, and PD cohort, as well as their matched controls. The database captures all episodes of patient care in which insurance was billed; this includes offices, clinics, emergency departments, and any inpatient hospital setting. Complications were assessed using ICD-9 and CPT codes and included the following: in-hospital death within 1 year, emergency department visit within 30 days of surgery, hospital readmission within 30 days of surgery, diagnosis of periprosthetic infection within 1 year, and revision surgery within 1 year.

Statistical analysis

Statistical comparisons of the annual incidence of shoulder arthroplasty in the dialysis-dependent population compared with the non–dialysis-dependent population were calculated using a linear regression analysis comparing the rate of increase between the groups. Statistical comparisons of the complications in each cohort were completed using a multivariate binomial logistic regression analysis controlling for the type of prosthesis implanted (hemiarthroplasty, conventional TSA, or reverse shoulder arthroplasty), year of procedure, age, sex, obesity, tobacco use, alcohol use, diabetes mellitus, hyperlipidemia, hypertension, peripheral vascular disease, congestive heart failure, coronary artery disease, chronic lung disease, chronic liver disease, thyroid disease, and depression. Odds ratios (ORs) with respective 95% confidence intervals (CIs) were calculated for all comparisons. For all statistical comparisons, $P < .05$ was considered significant. The embedded statistical software within PearlDiver was used for all statistical comparisons, which is based on the open-source R program (R Foundation for Statistical Computing, Vienna, Austria; www.r-project.org).

Results

Incidence of shoulder arthroplasty

The incidence of TSA in dialysis-dependent patients increased from 1.78 per 10,000 beneficiaries in 2005 to 7.36 in 2014, compared with an increase from 8.92 to 16.55 per 10,000 control patients (Fig. 1). There was a statistically significantly greater increase in dialysis-dependent patients compared with control patients ($P < .0001$).

Overall dialysis and complications

A total of 294,877 unique patients underwent shoulder arthroplasty during the period studied. Of these patients, 1225 were determined to be dialysis dependent, including 178 receiving PD and 1047 receiving HD. A total of 293,652 patients not receiving dialysis were available for matching. After implementation of the described 3:1 matching algorithm, 3675 control patients were matched to 1225 dialysis-dependent patients (Table I).

Compared with controls, patients receiving dialysis undergoing shoulder arthroplasty had significantly increased rates of in-hospital death within 1 year (OR, 7.60; $P < .0001$), emergency department visits within 30 days (OR, 4.16; $P < .0001$), hospital admission within 30 days (OR, 1.63; $P < .0001$), and infection within 1 year (OR, 1.90; $P = .009$) (Table II). We found no significant difference in the incidence of revision
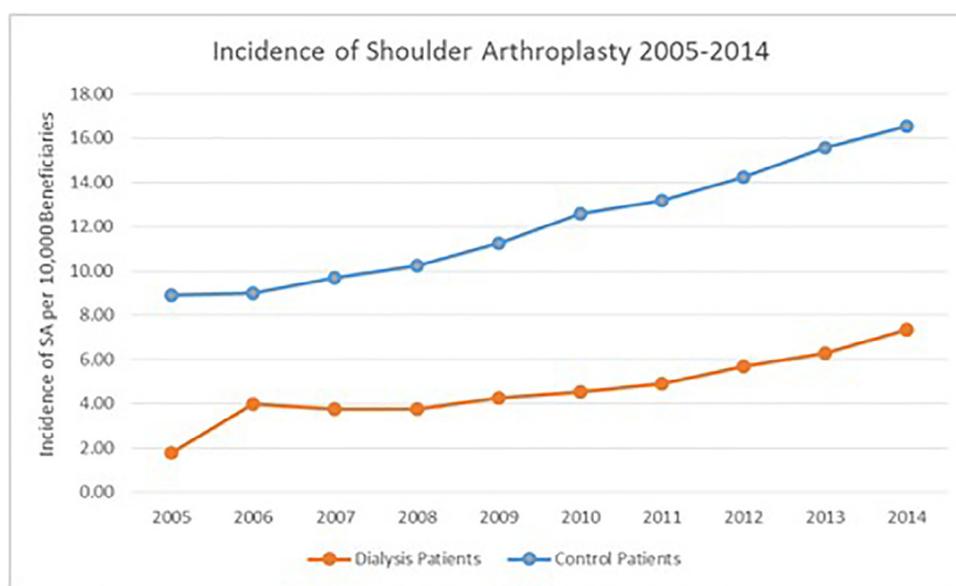

Figure 1 Annual incidence of shoulder arthroplasty (*SA*) per 10,000 beneficiaries in dialysis-dependent patients and control non–dialysis-dependent patients from 2005 to 2014.

Table I Demographic characteristics and comorbidities of dialysis and matched control groups

	Dialysis group (n = 1225)		Matched control group (n = 3675)	
	n	%	n	%
Demographic characteristics				
Age group				
<65 yr	463	37.8	1389	37.8
65-69 yr	223	18.2	669	18.2
70-74 yr	214	17.5	642	17.5
75-79 yr	195	15.9	585	15.9
80-84 yr	95	7.8	285	7.8
≥85 yr	35	2.9	105	2.9
Male sex	579	47.3	1737	47.3
Year of procedure				
2005	45	3.7	135	3.7
2006	99	8.1	297	8.1
2007	92	7.5	276	7.5
2008	96	7.8	288	7.8
2009	110	9.0	330	9.0
2010	118	9.6	354	9.6
2011	137	11.2	411	11.2
2012	152	12.4	456	12.4
2013	173	14.1	519	14.1
2014	203	16.6	609	16.6
Obesity (BMI of 30-39.9 kg/m²)	247	20.2	741	20.2
Morbid obesity (BMI ≥ 40 kg/m²)	283	23.1	849	23.1
Tobacco use	349	28.5	1047	28.5
Alcohol abuse	134	10.9	376	10.2
Comorbidities				
Diabetes mellitus	922	75.3	2766	75.3
Hyperlipidemia	1016	82.9	3058	83.2
Hypertension	1220	99.6	3394	92.4
Peripheral vascular disease	497	40.6	1345	36.6
Congestive heart failure	896	73.1	2275	61.9
Coronary artery disease	881	71.9	2570	69.9
Chronic lung disease	599	48.9	1745	47.5
Chronic liver disease	194	15.8	485	13.2
Thyroid disease	507	41.4	1485	40.4
Depression	616	50.3	1723	46.9

BMI, body mass index.

Table II Comparison and statistical analysis of adverse events and complications after shoulder arthroplasty between dialysis and matched control groups

Complication	Dialysis group		Matched control group		Comparison (dialysis vs control)		
	n	%	n	%	OR	95% CI	P value
In-hospital death (1 yr)	78	6.37	31	0.84	7.60	4.69-12.31	<.0001
ED visit (30 d)	166	13.55	98	2.67	4.16	3.11-5.56	<.0001
Hospital admission (30 d)	121	9.88	205	5.58	1.63	1.25-2.13	<.0001
Infection (1 yr)	37	3.02	46	1.25	1.90	1.40-2.58	.009
Revision (1 yr)	52	4.24	75	2.04	1.48	0.97-2.26	.067

OR, odds ratio; *CI*, confidence interval; *ED*, emergency department.

Table III Comparison and statistical analysis of adverse events and complications after shoulder arthroplasty in dialysis patients stratified by dialysis modality and matched control group

Complication	PD patients		HD patients		Matched controls		Comparison of PD vs HD			Comparison of PD vs control		
	n	%	n	%	n	%	OR	95% CI	P value	OR	95% CI	P value
In-hospital death (1 yr)	7	5.38	13	10.00	5	1.28	0.40	0.22-0.74	.008	4.87	1.24-19.16	.342
ED visit (30 d)	23	17.69	23	17.69	10	2.56	0.94	0.49-1.82	.855	6.88	2.91-16.26	<.0001
Hospital admission (30 d)	10	7.69	20	15.38	23	5.90	0.43	0.19-0.99	.047	1.06	0.46-2.46	.888
Infection (1 yr)	2	1.54	6	4.62	7	1.79	0.30	0.11-0.79	.018	0.79	0.14-4.47	.789
Revision (1 yr)	3	2.31	8	6.15	6	1.54	0.23	0.06-0.81	.037	1.36	0.28-6.63	.701

PD, peritoneal dialysis; *HD*, hemodialysis; *OR*, odds ratio; *CI*, confidence interval; *ED*, emergency department.

surgery within 1 year between dialysis-dependent patients and controls (*P* = .067).

Stratification by dialysis modality

Of the 178 patients receiving PD, 130 were able to be matched to 130 HD patients by use of the described matching algorithm. Subsequently, 390 controls were matched to these 130 PD patients. Compared with patients receiving HD, patients who underwent shoulder arthroplasty while receiving PD had significantly lower rates of in-hospital death within 1 year (OR, 0.40; *P* = .008), hospital readmission within 30 days (OR, 0.43; *P* = .047), and revision surgery within 1 year (OR, 0.23; *P* = .037), as well as a lower incidence of infection within 1 year (OR, 0.30; *P* = .018). We found no significant difference in the incidence of emergency department visits within 30 days between the 2 cohorts (*P* = .855) (Table III).

Compared with non–dialysis-dependent controls, patients receiving PD undergoing shoulder arthroplasty had similar rates of in-hospital death within 1 year (*P* = .342), readmission within 30 days (*P* = .888), infection within 1 year (*P* = .789), and revision surgery within 1 year (*P* = .701). Patients receiving PD had significantly higher rates of emergency department visits within 30 days of surgery compared with controls (OR, 6.88; *P* < .0001) (Table III).

Finally, compared with HD and PD patients undergoing shoulder arthroplasty, both HD and PD patients not undergoing shoulder arthroplasty had similar mortality rates. For PD patients, the mortality rate 1 year after shoulder arthroplasty (5.38%) was not substantially different than the 1-year mortality rate for patients not undergoing shoulder arthroplasty (6.67%) (OR, 0.75; 95% CI, 0.32-1.77; *P* = .518). For HD patients, the mortality rate 1 year after shoulder arthroplasty (10.00%) was not substantially different than the 1-year mortality rate for patients not undergoing shoulder arthroplasty (7.95%) (OR, 1.19; 95% CI, 0.58-2.45; *P* = .642).

Discussion

Despite an abundance of literature detailing the increased perioperative morbidity and mortality rates in dialysis-dependent patients undergoing lower-extremity total joint arthroplasty, no studies to date have investigated the impact

of this rising comorbidity on TSA outcomes.[9,14,16,18,19,23] Similarly to the lower-extremity arthroplasty literature, no literature has evaluated whether the type of dialysis treatment, PD or HD, confers any risk mitigation on such outcomes. Our study suggests an increasing number of shoulder arthroplasties being performed in the dialysis-dependent population over the period examined. Furthermore, dialysis dependence represents a significant independent risk factor for increased perioperative morbidity and mortality rates in the shoulder arthroplasty population. However, it appears that patients receiving PD have substantially decreased rates of measured complications compared with HD patients and that the rates are similar to those seen in the general population after shoulder arthroplasty.

Given the increasing number of shoulder arthroplasties performed in patients who are dialysis dependent over the past decade, it is imperative to determine the impact of dialysis on perioperative complications. As evidenced in our study, the impact of dialysis on surgical outcomes after shoulder arthroplasty is similar to that previously reported in the lower-extremity arthroplasty literature.[18] Ponnusamy et al[18] recently analyzed the inpatient morbidity and mortality rates in 2934 dialysis-dependent patients after total knee and hip arthroplasty by use of the National Inpatient Sample database. Similarly to our study, they reported that dialysis-dependent patients had higher inpatient mortality rates and greater overall complication rates, including wound infections requiring a return to the operating room. Of all the complications studied after shoulder arthroplasty, death is the most devastating. Our control inpatient mortality rate of 0.84% is similar to that reported in the broader shoulder arthroplasty literature.[2] In comparison, our mortality rate in the dialysis-dependent cohort was more than 7.5 times higher, a sobering reminder of the high-risk nature of performing this procedure in this population. To determine whether the shoulder arthroplasty procedure itself places dialysis-dependent patients at an increased mortality risk rather than the dialysis treatment itself, we compared the surgical cohort of PD and HD patients with a matched cohort of HD and PD patients not undergoing shoulder arthroplasty. The surgical cohort of dialysis-dependent patients showed no difference in mortality rate compared with nonsurgical dialysis-dependent matched controls, suggesting that the increased mortality risk seen in dialysis patients undergoing shoulder arthroplasty is due to the dialysis, not

the shoulder arthroplasty procedure. Although the cause of such a high rate is likely multifactorial, it is well established that the most common cause of death in dialysis-dependent patients is cardiovascular disease.[12] We found congestive heart failure in approximately 73% of our dialysis-dependent patients compared with 61% of our control cohort, although these numbers in the control population are likely skewed because they were matched for numerous other variables to the study population. Dialysis-dependent patients frequently acquire multiple-organ dysfunction, resulting in myriad comorbidities including liver disease, metabolic syndrome, and peripheral vascular disease.[18] A recent study by Mahure et al[15] used the Nationwide Inpatient Sample to identify patients with diabetes undergoing elective TSA and compared their demographic characteristics and in-hospital outcomes with those of patients without diabetes by use of a multivariate logistic regression. Diabetic patients tended to be older and to be of minority racial status, and they had a significantly greater medical comorbidity burden. After controlling for these differences with a regression analysis, Mahure et al reported that diabetes was an independent risk factor for non–home-bound discharge, length of stay, total charges, and postoperative acute renal failure. The demographic and comorbidity profiles of the dialysis-dependent and non–dialysis-dependent cohorts in our study were also markedly different. Similarly, despite controlling for these factors with a logistic regression analysis after matching a control cohort, we found that dialysis-dependent patients still carried a substantially higher risk of all complications studied, suggesting that the mechanisms behind the treatment and disease are incompletely understood. Given such high rates of perioperative complications, including inpatient death, extreme caution should be used when recommending elective shoulder arthroplasty for dialysis-dependent patients.

One facet of the relationship between dialysis dependence and perioperative complications after orthopedic surgery that has yet to be studied is the dialysis modality. In this study, we were able to distinctly compare the 2 modalities of dialysis to demonstrate that both HD and PD confer markedly different risk profiles to patients undergoing shoulder arthroplasty. The most likely explanation for these differences is the exceedingly higher risk of nearly constant bacteremia in HD patients compared with PD patients. Given the need for recurrent vascular access in HD patients, they have substantially higher rates of bacteremia and hospitalization.[3,11,21] Furthermore, over half of the causative organisms of bacteremia in HD patients are gram-positive bacteria, including resistant organisms such as methicillin-resistant *Staphylococcus aureus*.[7,22] As has been hypothesized in the lower-extremity arthroplasty literature, each episode of bacteremia risks the hematogenous seeding of the prosthesis, resulting in periprosthetic joint infection. As PD does not require continuous vascular access, this modality appears to carry less risk of bacteremia and periprosthetic joint infection. In addition, it appears to be associated with significantly lower rates of in-hospital death, hospital admission, and revision surgery.

It is well established that the higher frequency of bacteremia in HD patients results in substantially higher hospitalization and in-hospital mortality rates.[3,11,21] Although we are unable to determine the cause of readmission in our study, it is likely that the majority of these admissions and deaths are related to other medical comorbidities and not the orthopedic procedure. Given the excessive risks of performing lower-extremity arthroplasty in this patient population, prior authors have recommended against elective arthroplasty.[14,16,18] Although this may be true in the HD population, excluding PD patients might deny them the benefits of an improved quality of life with a risk profile that is similar to that in the non–dialysis-dependent population. Regardless of the shared decision that is made between the surgeon and the patient, multidisciplinary management in the perioperative period is paramount to reduce the risk of early readmission and perioperative complications in the dialysis population.

Similarly to other studies using national databases, this study has several limitations.[5,6] First, a limitation of all databases is the inability to control for confounding variables that are unidentifiable in the database. The decision between HD and PD in dialysis-dependent patients is influenced by many socioeconomic factors that are beyond the scope of our study. Many of these socioeconomic variables are unable to be identified within the database, and many also influence the incidence of the studied complications in this study. Furthermore, the strength of our analysis relies on the quality of the data and the accuracy with which the selected procedures and complications are coded. Therefore, miscoding and noncoding by providers are potential sources of error. We are unable to individually verify that patients coded as receiving PD or HD actually received such an intervention. Finally, we used a database that draws from a Medicare sample to capture 100% of dialysis patients in the United States. Thus, the conclusions of the study may not apply to a private-payer population.

Conclusion

Similar to outcomes seen in lower joint arthroplasty, dialysis dependence is associated with an increased risk of complications after TSA, including in-hospital death, emergency department visits, early readmission, periprosthetic joint infection, and all-cause revision TSA. The increased mortality rate after shoulder arthroplasty in dialysis-dependent patients appears to be related to the dialysis and not to the arthroplasty procedure itself. However, when we assessed these outcomes based on type of dialysis, the risk in PD patients approached that in the control population. Given the increasing number of dialysis-dependent patients presenting for elective shoulder arthroplasty evaluation, an understanding of the risks that each modality confers is indispensable when counseling patients. Finally, this study shows a clear need for further research

focusing on the mechanisms by which HD and PD impact orthopedic procedures such as shoulder arthroplasty.

Disclaimer

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