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Cumulative effect of chronic dehydration and age on postoperative complications after total shoulder arthroplasty

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A R T I C L E I N F O

Keywords:
Total shoulder arthroplasty
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Dehydration
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Level of evidence: Level III; Retrospective Cohort Comparison Using Large Database; Prognosis Study

Background: Dehydration is a modifiable risk factor that should be optimized prior to all surgical procedures. The aim of this study was to determine the effects of dehydration on postoperative complications following total shoulder arthroplasty (TSA).
Methods: The American College of Surgeons National Surgical Quality Improvement database was queried for all patients who underwent TSA between 2015 and 2019 and a total of 16,993 patients were included in this study. The study population was subsequently classified into 3 categories: 8498 (50.0%) nondehydrated patients with blood urea nitrogen/creatinine (BUN/Cr) < 20, 4908 (28.9%) moderately dehydrated patients with $20 \leq$ BUN/Cr ≤ 25, and 3587 (21.1%) severely dehydrated patients with $25 <$ BUN/Cr. A subgroup analysis involving only elderly patients aged > 65 years and normalized gender-adjusted Cr values was also performed. Postoperative complications within 30 days of the TSA were collected. Multivariate logistic regression analysis was conducted to explore the correlation between dehydration and postoperative complications.
Results: Adjusted multivariate logistic regression analysis showed that the severely dehydrated cohort had a greater risk of postoperative transfusion, mortality, nonhome discharge, and increased length of stay (all $P < .05$). The moderately dehydrated cohort had a greater risk of wound dehiscence ($P = .044$). Among the elderly, severely dehydrated patients had a greater risk of cardiac complications, postoperative transfusion, mortality, nonhome discharge, and increased length of stay (all $P < .05$). Finally, the elderly moderately dehydrated cohort had a greater risk of postoperative transfusion and nonhome discharge (all $P < .05$).
Conclusion: BUN/Cr ratio is an important preoperative diagnostic tool to identify at-risk dehydrated patients. Providers should optimize dehydration to prevent complications, decrease costs, and improve discharge planning.

As the elderly population expands and total shoulder arthroplasty (TSA) becomes more commonplace, it is vital to enhance patients' medical status before surgery to mitigate complications, curtail the duration of hospital stays, and boost functional recovery. The shift in healthcare economics toward outcome-based, bundled payment models further necessitates providers' strong understanding of preoperative medical optimization. Variables like fluid intake and fluid resuscitation, which can be altered and monitored before elective surgery, can play a crucial role.

Older patients often present with dehydration as well as medical comorbidities and increased sensitivity to anesthesia, placing them at a naturally increased risk of longer hospital stays and extended recovery periods.[35] Dehydration has been implicated as a factor contributing to orthostatic hypotension and weakness, which may negatively impact rehabilitation results and patient satisfaction following TSA.[17] Blood urea nitrogen (BUN) and creatinine (Cr) are laboratory values routinely obtained before TSA and have served in the past to define and estimate dehydration prevalence. A BUN/Cr ratio more than 20 can serve as an effective early warning sign to identify at-risk dehydrated patients prone to acute in-hospital complications.

Institutional review board approval was not required for this study.

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The BUN/Cr ratio's validity as a reliable indicator predicting dehydration has been established, as other physical and clinical signs such as low systolic blood pressure, increased heart rate, dry mucous membranes, and sunken eyes have shown inadequate sensitivity toward dehydration.[26]

The Centers for Medicare and Medicaid Services have identified 30-day readmissions and complication rates as quality measures for value-based care. Methods for detecting dehydration for swift intervention and optimization are evolving given that dehydration has been linked to various preventable complications like falls, delirium, renal impairment, and circulatory collapse.[2] Dehydration is a frequently overlooked modifiable risk factor that, if detected early, can lower the chances of acute kidney injury and cardiac stress due to circulatory collapse.[25] By enhancing orthostasis and circulatory function, patients might engage in physical therapy sooner, potentially accelerating functional recovery and improving their chances of being discharged home.[17]

Previous studies explored the correlation between BUN/Cr values and postoperative results. Renfree and his colleagues examined elective lumbar procedures in the National Surgical Quality Improvement Program (NSQIP) database and found that heightened preoperative BUN/Cr was associated with postoperative deep vein thrombosis, urinary tract infections, and the necessity for transfusion.[19] The high likelihood of orthopedic patients arriving dehydrated, coupled with the large volume of annual TSA procedures and the ease of preoperative blood tests, underscores the importance of determining if a high BUN/Cr level is a reliable forecaster of unfavorable postoperative outcomes and discharge dispositions. The purpose of this study was to examine the relationship between preoperative BUN/Cr levels and postoperative outcomes, aiming to improve clinical care and decision-making. We hypothesized that chronic preoperative dehydration is a predictor of postoperative complications, especially in the elderly population.

Methods

All patients who underwent either anatomic or reverse TSA between 2015 and 2019 were queried from the American College of Surgeons NSQIP database. As the NSQIP database is fully deidentified, this study was exempt from review and approval by our University's Institutional Review Board. Patient information included in the database is gathered from more than 600 healthcare facilities throughout the United States, obtained through various means such as interviews, outpatient visits, and examination of patient records.[5]

Current Procedural Terminology code 23472 was used to identify 22,542 patients who underwent TSA from 2015 to 2019. We excluded patients who had Cr values more than 1.3 mg/dL, those with a preoperative diagnosis of renal failure, or who were undergoing dialysis. By excluding patients with Cr levels exceeding 1.3 mg/dL, we avoided the inclusion of those with underlying renal disease and decreased glomerular filtration rates, which could have served as confounding variables.[1] Patients without available preoperative serum Cr or BUN values were also excluded. After applying these exclusion criteria, we were left with 16,993 cases for our statistical analysis. We divided the study population into 3 distinct groups, based on their hydration status. These 3 groups were formed according to BUN/Cr values: less than 20 (nondehydrated), between 20 and 25 (moderately dehydrated), and more than 25 (severely dehydrated). In addition, we performed a subgroup analysis involving 9739 cases of patients aged more than 65 years and with gender-adjusted normalized Cr values (more than 0.8 for males and more than 0.6 for females). Low Cr values have been associated with conditions like malnutrition, advanced liver disease, and nephrotic syndrome, which warranted exclusion from the analysis.[31]

Our study included a total of 16,993 patients who underwent TSA from 2015-2019. Of these patients, 8498 patients (50.0%) were in the nondehydrated cohort, 4908 patients (28.9%) were in the moderately dehydrated cohort, and 3587 patients (21.1%) were in the severely dehydrated cohort. A subgroup analysis of 9739 elderly patients revealed that 4689 patients (48.1%) were in the nondehydrated cohort, 2961 patients (30.4%) were in the moderately dehydrated cohort, and 2089 patients (21.4%) were in the severely dehydrated cohort.

We gathered data on various patient demographics, including race, gender, body mass index (BMI), age, smoking status, functional status, American Society of Anesthesiologists (ASA) physical status classification, corticosteroid usage, preoperative laboratory results, preoperative medical conditions, 30-day postoperative complications, and operative variables. Corticosteroid usage was deemed positive for patients who regularly ingested immunosuppressants or corticosteroids in the 30 days preceding the surgery. We considered patients to be smokers if they had smoked cigarettes at any point within the year leading up to the surgery. Use of other forms of tobacco or marijuana, such as e-cigarettes, cigars, or pipes, did not affect a patient's nonsmoking status. We classified patients as having severe systemic disease if their ASA physical status classification was 3 or more. We collected data on a range of preoperative medical conditions, including diabetes, severe chronic obstructive pulmonary disease, congestive heart failure (CHF), recent weight loss, bleeding disorders, transfusion history, previous sepsis, metastasized cancer, and dyspnea, ascites, among others. We analyzed postoperative complications occurring within 30 days, including cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, deep vein thrombosis, stroke, unplanned intubation, pulmonary embolism, prolonged ventilator usage (> 48 hours), acute renal failure, sepsis, septic shock, extended hospital stay (> 30 days), reoperation, readmission, death, progressive renal insufficiency, urinary tract infections, pneumonia, transfusions within 72 hours postsurgery, and surgical site infections.

We conducted all statistical analyses for this study using SPSS Software version 26.0 (IBM Corporation, Armonk, NY, USA). We performed a bivariate analysis to compare patient demographics, preoperative medical conditions, and surgical characteristics across different cohorts. We also carried out multivariate logistic regression analysis, adjusting for significantly associated variables such as patient demographics, preoperative medical conditions, and surgical variables, to explore the relationship between preoperative dehydration status and postoperative complications. We reported calculated odds ratios (ORs) in relation to the 95% confidence interval (CI). We set the statistical significance level at $P < .05$.

Results

In comparison to the nondehydrated cohort, both moderately and severely dehydrated cohorts had greater proportions of patients with the following demographics/comorbidities: age $\geq$ 75, female gender, BMI $\geq$ 40, dependent functional status, nonsmoking status, diabetes (both insulin-dependent and noninsulin-dependent), CHF, hypertension, and chronic steroid use (Table I). Compared to the moderately dehydrated cohort, the severely dehydrated cohort had higher proportion of patients with the following demographics/comorbidities: age $\geq$ 75, female gender, ASA classification of 3 or more, dependent functional status, nonsmoking status, insulin-dependent diabetes, CHF, hypertension, and chronic steroid use (Table I). A subgroup analysis of elderly patients with gender-adjusted normalized Cr values revealed that in comparison to the nondehydrated cohort, both

Table I
Comparison of patient demographics, medical comorbidities, and operative characteristics between dehydration status cohorts.

Characteristic	Nondehydrated		Moderately dehydrated		Severely dehydrated		*P* value
	N	Percent (%)	N	Percent (%)	N	Percent (%)	
Total	8498	100	4908	100	3587	100	
Days from laboratories to surgery							
Same day	445	5.24	256	5.22	221	6.16	.548
1 d-2 weeks	4578	53.87	2611	53.20	1940	54.08	.678
>2 weeks	3475	40.89	2041	41.59	1426	39.75	.270
Age							
18-39	71	0.84	8	0.16	5	0.14	**<.001**
40-64	2879	33.88	1196	24.37	696	19.40	**<.001**
65-74	3430	40.36	2096	42.71	1525	42.51	.084
≥75	2118	24.92	1608	32.76	1361	37.94	**<.001**
Gender							**<.001**
Female	4034	47.47	2998	61.08	2756	76.83	
Male	4464	52.53	1910	38.92	831	23.17	
Body mass index (kg/m^2)							
<18.5	59	0.69	31	0.63	34	0.95	.296
18.5-29.9	4078	47.99	2315	47.17	1686	47.00	.966
30-34.9	2320	27.30	1278	26.04	922	25.70	.211
35-39.9	1191	14.02	695	14.16	515	14.36	.901
≥40	850	10.00	589	12.00	430	11.99	**.001**
ASA classification							**.028**
1-2	3636	42.79	2104	42.87	1447	40.34	
≥3	4862	57.21	2804	57.13	2140	59.66	
Functional status							**<.001**
Independent	8355	98.32	4812	98.04	3477	96.93	
Dependent	143	1.68	96	1.96	110	3.07	
Smoking							**<.001**
No	7311	86.03	4509	91.87	3323	92.64	
Yes	1187	13.97	399	8.13	264	7.36	
Outpatient/inpatient							.632
Outpatient	791	9.31	440	8.96	316	8.81	
Inpatient	7707	90.69	4468	91.04	3271	91.19	
Diabetes							
No	7078	83.29	3992	81.34	2879	80.26	**.012**
Noninsulin	1047	12.32	700	14.26	504	14.05	**.028**
Insulin	373	4.39	216	4.40	204	5.69	**.021**
Dyspnea							
No	7942	93.46	4614	94.01	3337	93.03	.206
Moderate exertion	529	6.22	280	5.70	234	6.52	.354
At rest	27	0.32	14	0.29	16	0.45	.652
COPD							**.004**
No	7858	92.47	4605	93.83	3359	93.64	
Yes	640	7.53	303	6.17	228	6.36	
Ascites							.154
No	8498	100.00	4908	100.00	3586	99.97	
Yes	0	0.00	0	0.00	1	0.03	
Congestive heart failure							**.010**
No	8464	99.60	4877	99.37	3557	99.16	
Yes	34	0.40	31	0.63	30	0.84	
Hypertension							**<.001**
No	2926	34.43	1589	32.38	1034	28.83	
Yes	5572	65.57	3319	67.62	2553	71.17	
Disseminated cancer							.649
No	8480	99.79	4894	99.71	3577	99.72	
Yes	18	0.21	14	0.29	10	0.28	
Chronic steroid use							**.007**
No	8128	95.65	4662	94.99	3384	94.34	
Yes	370	4.35	246	5.01	203	5.66	
Bleeding disorders							.632
No	8286	97.51	4790	97.60	3508	97.80	
Yes	212	2.49	118	2.40	79	2.20	

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

moderately and severely dehydrated cohorts had greater proportions of patients with the following demographics/comorbidities: age ≥ 75, female gender, BMI ≥ 40, dependent functional status, nonsmoking status, and hypertension (Table II). Compared to the moderately dehydrated cohort, the severely dehydrated cohort had higher proportion of patients with the following demographics/comorbidities: age ≥ 75, female gender, dependent functional status, insulin-dependent diabetes, CHF, and hypertension (Table II). There were no statistically significant differences in the number of days from laboratories drawn to surgery in both the general and elderly groups (Tables I and II). These data are depicted in Figures 1 and 2.

Table II
Comparison of patient demographics, medical comorbidities, and operative characteristics between elderly dehydration status cohorts (subgroup analysis).

Characteristic	Nondehydrated		Moderately dehydrated		Severely dehydrated		*P* value
	N	Percent (%)	N	Percent (%)	N	Percent (%)	
Total	4689	100	2961	100	2089	100	
Days from laboratories to surgery							
Same day	249	5.31	143	4.83	122	5.84	.338
1 d-2 weeks	2501	53.34	1577	53.26	1142	54.67	.932
> 2 weeks	1939	41.35	1241	41.91	825	39.49	.255
Age							
18-39	0	0.00	0	0.00	0	0.00	-
40-64	0	0.00	0	0.00	0	0.00	-
65-74	2759	58.84	1558	52.62	1030	49.31	**<.001**
≥ 75	1930	41.16	1403	47.38	1059	50.69	**<.001**
Gender							**<.001**
Female	2479	52.87	2032	68.63	1728	82.72	
Male	2210	47.13	929	31.37	361	17.28	
Body mass index (kg/m^2)							
<18.5	28	0.60	21	0.71	16	0.77	.900
18.5-29.9	2392	51.01	1470	49.65	983	47.06	**.008**
30-34.9	1278	27.26	772	26.07	552	26.42	.765
35-39.9	623	13.29	387	13.07	290	13.88	.901
≥40	368	7.85	311	10.50	248	11.87	**<.001**
ASA classification							.252
1-2	1770	37.75	1161	39.21	774	37.05	
≥3	2919	62.25	1800	60.79	1315	62.95	
Functional status							**.034**
Independent	4594	97.97	2890	97.60	2025	96.94	
Dependent	95	2.03	71	2.40	64	3.06	
Smoking							**<.001**
No	4352	92.81	2833	95.68	1998	95.64	
Yes	337	7.19	128	4.32	91	4.36	
Outpatient/inpatient							.357
Outpatient	366	7.81	251	8.48	155	7.42	
Inpatient	4323	92.19	2710	91.52	1934	92.58	
Diabetes							
No	3851	82.13	2420	81.73	1652	79.08	**.009**
Noninsulin	622	13.27	420	14.18	315	15.08	.137
Insulin	216	4.61	121	4.09	122	5.84	**.012**
Dyspnea							
No	4351	92.79	2769	93.52	1922	92.01	.119
Moderate exertion	321	6.85	182	6.15	156	7.47	.193
At rest	17	0.36	10	0.34	11	0.53	.913
COPD							**.030**
No	4321	92.15	2753	92.98	1962	93.92	
Yes	368	7.85	208	7.02	127	6.08	
Ascites							-
No	4689	100.00	2961	100.00	2089	100.00	
Yes	0	0.00	0	0.00	0	0.00	
Congestive heart failure							**.012**
No	4663	99.45	2945	99.46	2065	98.85	
Yes	26	0.55	16	0.54	24	1.15	
Hypertension							**<.001**
No	1326	28.28	806	27.22	472	22.59	
Yes	3363	71.72	2155	72.7	1167	77.41	
Disseminated cancer							.578
No	4679	99.79	2951	99.66	2083	99.71	
Yes	10	0.21	10	0.34	6	0.29	
Chronic steroid use							.437
No	4480	95.54	2821	95.27	1981	94.83	
Yes	209	4.46	140	4.73	108	5.17	
Bleeding disorders							.312
No	4555	97.14	2887	97.50	2042	97.75	
Yes	134	2.86	74	2.50	47	2.25	

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

An increasing rate of blood transfusions was observed as the severity of dehydration progressed from nondehydrated (1.45%) to moderately dehydrated (1.69%) and to severely dehydrated (2.48%) ($P < .001$). A similar pattern was seen for nonhome discharge (8.03%, 9.60%, 14.08%; $P < .001$) and increased length of stay (LOS) (34.12%, 35.49%, 38.56%; $P < .001$) (Table III). A subgroup analysis of elderly patients with gender-adjusted normalized Cr values also showed a similar pattern as the severity of dehydration progressed for blood transfusions (1.56%, 2.16%, 2.68%; $P = .006$), mortality (0.04%, 0.10%, 0.38%; $P = .002$), nonhome discharge (10.39%, 12.16%, 16.18%; $P < .001$), and increased LOS (36.89%, 38.86%, 41.03%; $P = .004$) (Table IV).

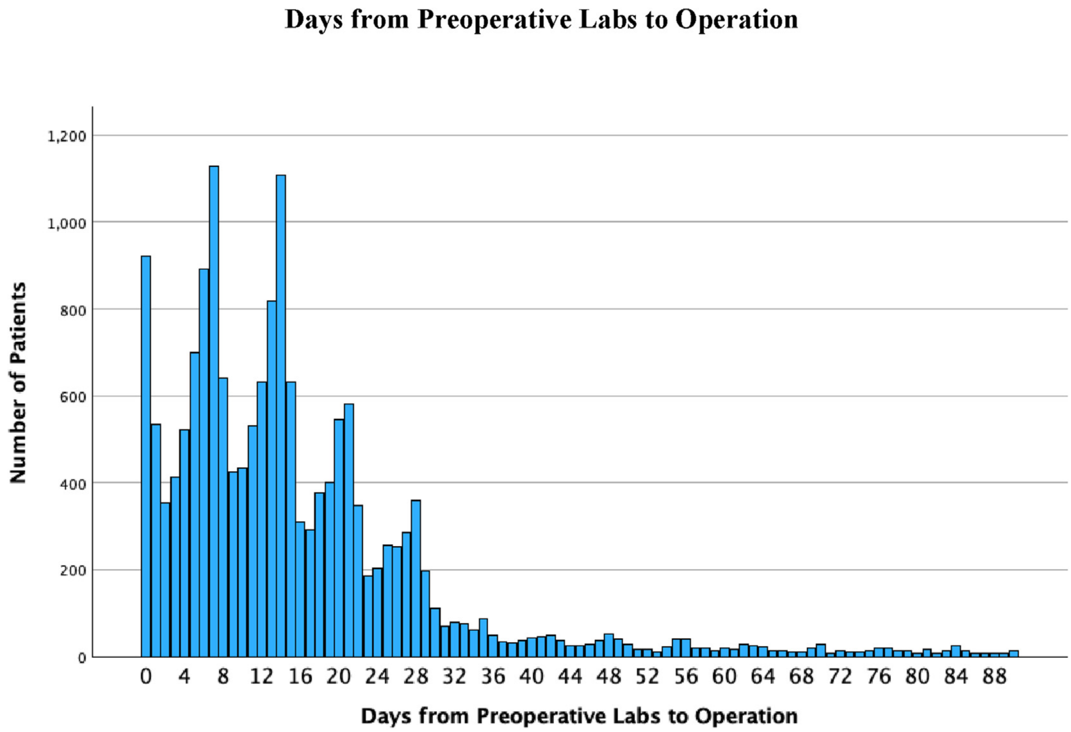

Figure 1 Days from preoperative laboratories to operation

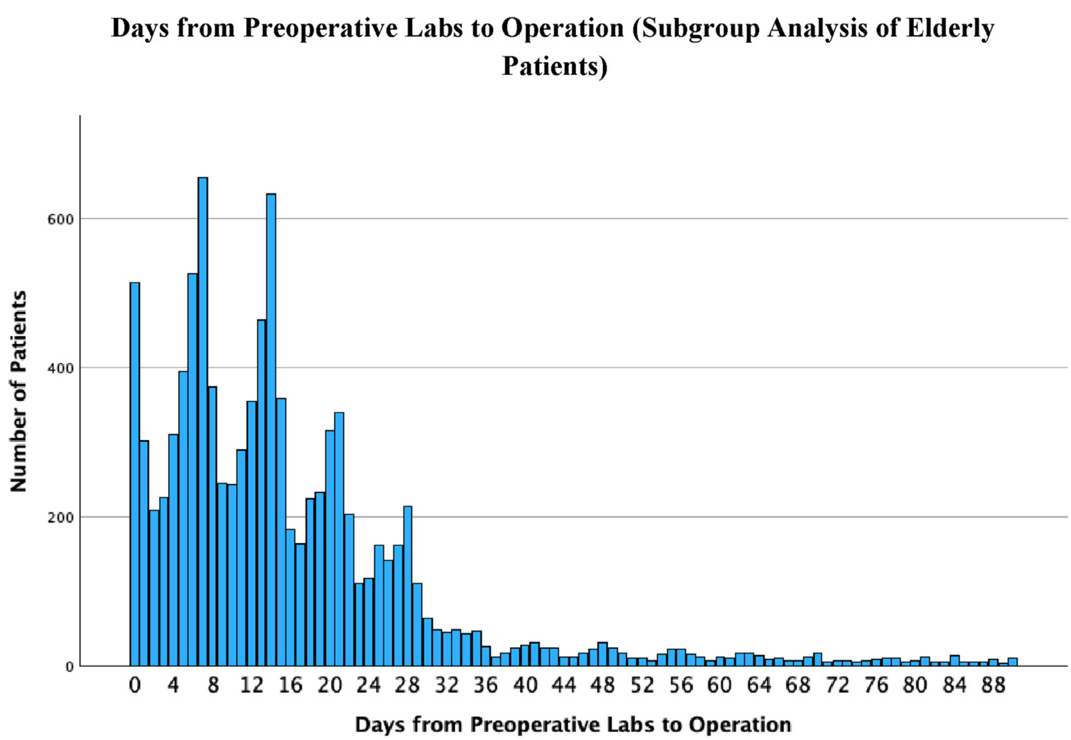

Figure 2 Days from preoperative laboratories to operation (subgroup analysis of elderly patients)

After controlling for all associated patient demographics and comorbidities, adjusted multivariate logistic regression analysis showed that the severely dehydrated cohort had a greater risk of developing the following complications compared to the non-dehydrated cohort: blood transfusions (OR, 1.52; 95% CI, 1.14-2.01; $P = .004$), mortality (OR, 2.44; 95% CI, 1.02-5.81; $P = .045$),

Table III
Comparison of complication rates following total shoulder arthroplasty between dehydration status cohorts.

Postoperative complication	Nondehydrated		Moderately dehydrated		Severely dehydrated		P value
	N	Percent (%)	N	Percent (%)	N	Percent (%)	
Superficial SSI	19	0.22	13	0.26	8	0.22	.880
Deep SSI	7	0.08	3	0.06	0	0.00	.233
Organ space SSI	26	0.31	6	0.12	5	0.14	**.047**
Reoperation	131	1.54	60	1.22	41	1.14	.134
Wound dehiscence	3	0.04	5	0.10	1	0.03	.208
Stroke/CVA	4	0.05	6	0.12	2	0.06	.268
Cardiac complications	21	0.25	11	0.22	18	0.50	**.034**
Respiratory complications	64	0.75	39	0.79	42	1.17	.064
Renal complications	6	0.07	4	0.08	4	0.11	.774
Urinary tract infection	51	0.60	30	0.61	30	0.84	.308
Bleeding transfusions	123	1.45	83	1.69	89	2.48	**<.001**
Deep vein thrombosis	36	0.42	15	0.31	14	0.39	.564
Sepsis/septic shock	16	0.19	4	0.08	9	0.25	.150
Readmission	254	2.99	125	2.55	109	3.04	.267
Mortality	10	0.12	3	0.06	12	0.33	**.003**
Nonhome discharge	682	8.03	471	9.60	505	14.08	**<.001**
LOS of 2 or more days	2899	34.12	1741	35.49	1381	38.56	**<.001**

SSI, surgical site infection; *CVA*, cerebrovascular accident; *LOS*, length of stay.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

Table IV
Comparison of complication rates following total shoulder arthroplasty between elderly dehydration status cohorts (subgroup analysis).

Postoperative complication	Nondehydrated		Moderately dehydrated		Severely dehydrated		P value
	N	Percent (%)	N	Percent (%)	N	Percent (%)	
Superficial SSI	7	0.15	9	0.30	3	0.14	.274
Deep SSI	1	0.02	1	0.03	0	0.00	.711
Organ space SSI	9	0.19	2	0.07	2	0.10	.303
Reoperation	56	1.19	27	0.91	20	0.96	.441
Wound dehiscence	0	0.00	1	0.03	0	0.00	.318
Stroke/CVA	4	0.09	4	0.14	1	0.05	.589
Cardiac complications	10	0.21	9	0.30	11	0.53	.099
Respiratory complications	40	0.85	29	0.98	24	1.15	.506
Renal complications	3	0.06	1	0.03	4	0.19	.130
Urinary tract infection	34	0.73	18	0.61	21	1.01	.263
Bleeding transfusions	73	1.56	64	2.16	56	2.68	**.006**
Deep vein thrombosis	16	0.34	9	0.30	9	0.43	.747
Sepsis/septic shock	9	0.19	1	0.03	4	0.19	.167
Readmission	137	2.92	83	2.80	72	3.45	.382
Mortality	2	0.04	3	0.10	8	0.38	**.002**
Nonhome discharge	487	10.39	360	12.16	338	16.18	**<.001**
LOS of 2 or more days	1729	36.89	1150	38.86	855	41.03	**.004**

SSI, surgical site infection; *CVA*, cerebrovascular accident; *LOS*, length of stay.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

nonhome discharge (OR, 1.51; 95% CI, 1.32-1.72; $P < .001$), and increased LOS (OR, 1.12; 95% CI, 1.03-1.22; $P = .007$) (Table V). The moderately dehydrated cohort had a greater risk of developing wound dehiscence (OR, 4.98; 95% CI, 1.04-23.73; $P = .044$) compared to the nondehydrated cohort.

The subgroup analysis of elderly patients with gender-adjusted normalized Cr values revealed that the severely dehydrated cohort had a greater risk of developing the following complications compared to the nondehydrated cohort: cardiac arrest or myocardial infarction (OR, 2.42; 95% CI, 1.02-5.76; $P = .046$), blood transfusions (OR, 1.81; 95% CI, 1.26-2.58; $P = .001$), mortality (OR, 9.10; 95% CI, 1.92-43.11; $P = .005$), nonhome discharge (OR, 1.64; 95% CI, 1.41-1.92; $P < .001$), and increased LOS (OR, 1.18; 95% CI, 1.06-1.31; $P = .003$) (Table VI). In addition, the moderately dehydrated cohort had a greater risk to develop blood transfusions (OR, 1.44; 95% CI, 1.02-2.02; $P = .038$) and nonhome discharge (OR, 1.12; 95% CI, 1.03-1.39; $P < .017$) compared to the nondehydrated cohort (Table VI).

Discussion

This study used a national database to identify chronic preoperative dehydration as an independent predictor of several adverse postoperative outcomes following TSA. These included the need for a transfusion, an increased mortality rate, discharge to a nonhome location, an extended LOS, and wound dehiscence. The risk of developing these complications was higher overall in elderly patients compared to the general population. Furthermore, elderly patients suffering from severe dehydration were found to be particularly prone to cardiac complications.

The findings of this study underline the critical importance of managing preoperative dehydration, a modifiable risk factor. With the expanding applications of TSA, healthcare practitioners must prepare themselves for a surge in the medical comorbidities among the elderly. Identifying and controlling preoperative risk factors, in conjunction with risk stratification, can significantly contribute to

Table V
Association between risk of complications following total shoulder arthroplasty and dehydration status cohort classification.

Postoperative complications	Moderately dehydrated		Severely dehydrated	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Superficial SSI	1.24 (0.61-2.53)	.558	1.06 (0.45-2.46)	.900
Deep SSI	0.92 (0.23-3.64)	.904	0.00 (0.00-0.00)	.981
Organ space SSI	0.46 (0.19-1.13)	.091	0.56 (0.21-1.49)	.247
Reoperation	0.82 (0.60-1.13)	.223	0.75 (0.52-1.07)	.117
Wound dehiscence	4.98 (1.04-23.73)	**.044**	1.77 (0.17-18.92)	.635
Stroke/CVA	2.50 (0.69-8.98)	.161	0.76 (0.14-4.23)	.751
Cardiac complications	0.86 (0.41-1.79)	.676	1.79 (0.94-3.40)	.078
Respiratory complications	1.05 (0.70-1.57)	.830	1.45 (0.97-2.16)	.071
Renal complications	1.17 (0.32-4.22)	.813	1.62 (0.44-5.95)	.471
Urinary tract infection	0.90 (0.57-1.43)	.666	1.15 (0.73-1.82)	.556
Bleeding transfusions	1.12 (0.84-1.48)	.457	1.52 (1.14-2.01)	**.004**
Deep vein thrombosis	0.75 (0.41-1.39)	.357	0.94 (0.50-1.78)	.852
Sepsis/septic shock	0.46 (0.15-1.39)	.168	1.36 (0.59-3.14)	.478
Readmission	0.86 (0.69-1.07)	.170	0.97 (0.76-1.22)	.772
Mortality	0.49 (0.13-1.81)	.286	2.44 (1.02-5.81)	**.045**
Nonhome discharge	1.09 (0.95-1.24)	.214	1.51 (1.32-1.72)	**<.001**
LOS of 2 or more days	1.04 (0.96-1.12)	.337	1.12 (1.03-1.22)	**.007**

CI, confidence interval; *SSI*, surgical site infection; *CVA*, cerebrovascular accident; *LOS*, length of stay.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

Table VI
Association between risk of complications following total shoulder arthroplasty and elderly dehydration status cohorts (subgroup analysis).

Postoperative complications	Moderately dehydrated		Severely dehydrated	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Superficial SSI	2.03 (0.75-5.49)	.164	0.93 (0.24-3.62)	.912
Deep SSI	1.98 (0.10-40.15)	.657	0.00 (0.00-0.00)	.983
Organ space SSI	0.39 (0.08-1.80)	.225	0.56 (0.12-2.60)	.457
Reoperation	0.76 (0.48-1.21)	.240	0.74 (0.44-1.25)	.257
Wound dehiscence	0.00 (0.00-0.00)	.970	0.00 (0.00-0.00)	.999
Stroke/CVA	1.56 (0.39-6.27)	.535	0.43 (0.05-3.91)	.454
Cardiac complications	1.41 (0.57-3.49)	.456	2.42 (1.02-5.76)	**.046**
Respiratory complications	1.13 (0.69-1.83)	.632	1.28 (0.77-2.15)	.343
Renal complications	0.49 (0.05-4.76)	.540	2.62 (0.58-11.89)	.211
Urinary tract infection	0.79 (0.44-1.42)	.434	1.36 (0.78-2.37)	.277
Bleeding transfusions	1.44 (1.02-2.02)	**.038**	1.81 (1.26-2.58)	**.001**
Deep vein thrombosis	0.86 (0.38-1.95)	.708	1.28 (0.56-2.90)	.561
Sepsis/septic shock	0.18 (0.02-1.45)	.108	1.05 (0.32-3.45)	.938
Readmission	0.96 (0.72-1.27)	.759	1.15 (0.86-1.55)	.338
Mortality	2.36 (0.39-14.16)	.347	9.10 (1.92-43.11)	**.005**
Nonhome discharge	1.12 (1.03-1.39)	**.017**	1.64 (1.41-1.92)	**<.001**
LOS of 2 or more days	1.09 (0.99-1.20)	.083	1.18 (1.06-1.31)	**.003**

CI, confidence interval; *SSI*, surgical site infection; *CVA*, cerebrovascular accident; *LOS*, length of stay.
Significance set to $P < .05$.
Bold values indicate statistically significant values ($P < .05$).

the reduction of hospital costs.[21,22] Furthermore, it can bolster the communication between the physician and the patient, providing clear expectations regarding the probable outcomes and the plans for discharge.[27] Dehydration is a common issue found among elderly patients undergoing arthroplasty, primarily due to decreased total body water. Often, these patients also suffer from disabilities, chronic fatigue, and orthostatic hypotension. These conditions pose further challenges toward regaining functional independence.[12] Despite the preventability of dehydration, the value of BUN/Cr as a reliable predictor of postoperative complications is frequently overlooked in clinical practice.[3] Specifically, the ratio of BUN to Cr can be useful to differentiate prerenal from renal causes when the BUN is increased. In prerenal causes such as chronic dehydration, the ratio is close to 20:1, while in intrinsic renal disease such as acute kidney failure, it is closer to 10:1.[7]

This study identified a significant prevalence of dehydration among TSA patients, with 50% of all patients and 51.9% of elderly patients affected before surgery. This highlights the widespread nature of dehydration, a condition frequently documented in Medicare hospitalization reports.[34] Factors such as older age and female gender were also associated with preoperative dehydration. This can likely be attributed to physiological changes linked to aging and a smaller body surface area, which can exacerbate fluid and electrolyte imbalances.[10] Moreover, dehydrated patients were more likely to have hypertension. This correlation might stem from chronic insufficient water intake, which can boost the activity of serum and glucocorticoid-inducible kinase 1, a key player in the onset of hypertension.[13] In line with previous research, smokers showed a lower likelihood of dehydration, potentially due to alterations in creatinine clearance.[8,18] Additionally, this study found a higher propensity for dehydration among diabetic patients. High blood glucose levels can trigger intravascular hypertonicity and osmotic diuresis, resulting in a deficiency in intracellular fluid.[14]

Cardiac function is inextricably linked to fluid status,[15] and this is of particular importance for patients undergoing surgery of any kind. The present study identified poor hydration as a strong independent predictor of postoperative myocardial infarction or cardiac arrest in elderly individuals undergoing TSA. This information is particularly pertinent to older patients, who often have a history of cardiac issues and varying levels of autonomic dysfunction. With normal aging or due to certain health conditions, the efficiency of the autonomic nervous system gradually diminishes.[16] Dehydration can lead to an elevated heart rate, increased blood pressure, and overall cardiac stress.[6,16] This added burden can heighten the risk of myocardial infarction or cardiac arrest in elderly patients, who may already have compromised heart function.

Our findings suggest that, compared to euvolemic patients, dehydrated patients are more likely to be transferred to a skilled nursing facility or rehabilitation unit and require hospital stays of more than 2 days. Increased duration of stay due to preoperative dehydration has significant implications for billing, hospital bed availability, and hospital service quality metrics. Effective preoperative hydration management is particularly critical in elderly patients, who are at a higher risk for hospital-acquired infections and increased frailty. Optimizing hydration status before surgery could potentially reduce complications associated with hypohydration.[28]

In addition, preoperative dehydration was as an independent risk factor for postoperative anemia necessitating blood transfusions. Multiple studies have reported an increased risk of postoperative infections, extended hospital stays, higher mortality rates, increased strain on the circulatory system, and elevated costs linked to postoperative allogenic blood transfusions.[20] Given that TSA can potentially lead to significant perioperative blood loss, it is vital for healthcare providers to understand that hemoglobin concentration can fluctuate significantly depending on the intravascular volume levels within a brief timeframe.[25] In many cases, patients seen during preoperative clinic visits might present with seemingly normal or high hemoglobin levels due to hemoconcentration, potentially concealing an underlying pre-existing anemia. Anesthetic agents used during surgery can cause further hypotension, necessitating the administration of crystalloid fluids. These fluids can reverse the effects of hemoconcentration, potentially revealing postoperative anemia that requires transfusion.[25] This could explain the drastic decline in hemoglobin levels following TSA, even when minimal blood losses are reported during the surgery.

Identifying dehydrated patients who are at risk based on individual clinical symptoms, fluid balance records, and independent tests can be a challenging task for healthcare providers. However, past research has recognized the BUN/Cr ratio as a dependable laboratory marker for dehydration.[9] This study is distinctive in its approach, as it not only categorizes dehydrated patients and the different degrees of dehydration for complications but it also performs a subgroup analysis of elderly patients to account for age-related variations in fluid and electrolyte management. Although a BUN/Cr ratio more than 20 has been traditionally used as a benchmark for identifying dehydration, recent geriatric research has revealed the usefulness of ratios more than 25 to signal severe dehydration.[23,29,30,32] To isolate dehydration, rather than kidney dysfunction, as an independent risk factor for complications, we excluded cases with serum creatinine levels exceeding 1.3 mg/dL.[24] Both genders have shown a correlation between levels higher than 1.3 and a decrease in the glomerular filtration rate, indicating renal dysfunction. Conversely, creatinine may be low due to malnutrition or low muscle mass. Our study accounted for abnormal creatinine levels and excluded patients with low creatinine levels from our elderly subgroup cohort.

For patients with preoperative dehydration, intervention often depends on the severity and the underlying causes. Increasing oral fluid intake may be beneficial for patients with mild to moderate dehydration. This is supported by one study which demonstrated the advantages of liquid intake up to 2 hours before surgery by reducing the risk of complications associated with dehydration.[33] Patients with severe dehydration or a history of renal disease may also benefit from consultation with a primary care physician or a nephrologist. These specialists can aid with fluid management and determine the need for intravenous fluid therapy. Finally, if the initial results suggest significant dehydration, it might be advisable to repeat the laboratories before surgery.

There are some key limitations related to data collection and study design that warrant further investigation. Although the dataset was derived from a diverse population nationwide and from various preoperative ambulatory settings, the broad range of in-patient hospital environments and varying levels of surgical expertise may influence outcomes. Different institutions may have different preoperative procedures for elective TSA, but including patients from both academic and private practices in rural and urban centers enhances the generalizability of our results. In addition, the absence of information regarding the use of potentially nephrotoxic medications, such as anti-inflammatories, or the occurrence of perioperative fevers could potentially affect BUN/Cr levels, leading to elevated levels that may not be directly attributable to dehydration status. Presurgical fasting might also cause slight variations in BUN/Cr levels.

Finally, our study could only include patients with available BUN/Cr to identify dehydration, as information concerning perioperative hydrotherapy or urinary indices was absent from the database. While urinary indices might assist in confirming dehydration, prior research has indicated that urine color, urine specific gravity, and urine osmolality provide limited diagnostic value in elderly patients due to age-related alterations in kidney function and urine concentration.[9] Nevertheless, the principal strength of our study is its robust sample size, which facilitated the detection of relationships between dehydration and less common postoperative complications such as cardiac complications. It has also been shown in the literature that the robustness of the NSQIP database is superior to other national databases in terms of consistency, completion of data input, and accuracy.[4,11,36] Furthermore, this study was able to adjust for many comorbidities and patient characteristics in our multivariate analysis. Finally, this study has broad implications to the preoperative screening and optimization of patients undergoing shoulder arthroplasty.

Conclusion:

BUN/Cr ratio serves as a crucial preoperative diagnostic tool for identifying dehydrated patients who are at risk and preparing to undergo elective TSA. Chronic dehydration, frequently an underrecognized and modifiable risk factor, should be proactively managed before elective TSA, particularly in older patients. Doing so can help decrease the likelihood of postoperative transfusion, mortality, discharge to facilities other than home, cardiac complications, and lengthened hospital stays.

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