RESEARCH ARTICLE

Identification of Risk Factors for Abnormal Postoperative Chemistry Labs after Primary Shoulder Arthroplasty

Alexis A. Williams, MD; Eric H. Tischler, BA; Daniel Sholder, BS; Thema A. Nicholson, MSc; Mitchell G. Maltenfort, PhD; Charles Getz, MD; Gerald Williams Jr, MD; Surena Namdari, MD, MSc

Research performed at Rothman Institute, Thomas Jefferson University, Philadelphia, PA, USA

Received: 28 November 2017 *Accepted: 04 February 2018*

Abstract

Background: The purpose of this study was to determine patient-specific risk factors and clinical intervention rates for abnormal postoperative Chem-7 panels in shoulder arthroplasty patients.

Methods: Retrospectively, all primary anatomic total (aTSA) and reverse shoulder (RTSA) arthroplasties (between 2007-2013) performed at a single institution were identified. All patients underwent routine preoperative and postoperative day one (POD1) chemistry panels. Each clinically significant component of the Chem-7 panel was independently evaluated using a multivariate analysis to identify risk factors for abnormal results. Associated clinical intervention rates were also calculated.

Results: Data from 1,012 patients (248 RTSA; 764 aTSA) was analyzed. 5.4% of patients had at least one preoperative abnormal chemistry result. On multivariate analysis, patients with abnormal preoperative Chem-7 labs and a history of renal disease had significantly increased risk for abnormal POD1 labs (*P<0.001*). Although 25.6% (259/1,012) of patients had at least one abnormal POD1 lab result, the total postoperative clinical intervention rate was 15.1% (39/259).

Conclusion: Renal disease and a preoperative abnormal chemistry result are important risk factors for abnormal postoperative Chem-7. Optimizing renal status and correcting abnormal blood chemistry results preoperatively may reduce the incidence of abnormal postoperative chemistry results.

Level of evidence: III

Keywords: Blood chemistry, Laboratory order, Reverse shoulder arthroplasty, Risk stratification, Total shoulder arthroplasty

Introduction

The postoperative course following shoulder arthroplasty often involves routine postoperative laboratory testing on the day after surgery. Obtaining postoperative laboratory tests on all patients is often unnecessary; however, certain patient populations may be at higher risk for abnormal postoperative laboratory results (1, 2). The majority of studies that report laboratory test rates and utility have been in cardiac and intensive care patient populations, and have shown that, even when lab tests were abnormal,

Corresponding Author: Surena Namdari, Rothman Institute, Thomas Jefferson University, Shoulder & Elbow Surgery, Philadelphia, PA, USA
Email: surena.namdari@rothmaninstitute.com

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

intervention rates were quite low (3-5).

Current literature has shown that both anatomical total shoulder arthroplasty (aTSA) and reverse total shoulder arthroplasty (RTSA), are well-tolerated procedures that can lead to successful clinical outcomes (6-8). Despite the fact that the vast majority of patients have an uncomplicated hospital course, patients often receive the same postoperative care. This includes a routine blood chemistry panel draw on the first postoperative day that consists of sodium (Na^+); potassium (K^+); chloride (Cl^-); carbon dioxide (CO_2); blood urea nitrogen (BUN); creatinine (Cr); and glucose. This current practice may be clinically unnecessary for many patients, increase the risk for harmful interventions due to false-positive values, and increase cost of care (2, 3, 6). The purpose of this study was three-fold: first, to report the rate of abnormal chemistry panel results in the perioperative period; second, to identify specific risk factors associated with those abnormal perioperative chemistry panel results; and third, to determine the postoperative clinical intervention rates for abnormal postoperative chemistry labs in a RTSA and aTSA surgical patient cohort.

Materials and Methods

Following institutional review board approval, our electronic institutional database was searched between 2007-2013 for all cases of primary aTSA and RTSA. Patients were excluded if complete preoperative and postoperative blood chemistry was not available.

All patients underwent chemistry panel testing both preoperatively and on postoperative day (POD) 1. Results for individual components of the chemistry panel (Na^+, K^+, Cl^-, CO_2, BUN, Cr, and Glucose) were collected. Glucose results were excluded from the analysis because AccuCheck results, and not the glucose level from the chemistry panel, determined blood glucose management and associated clinical interventions. Additionally, Cl^- and CO_2 results were excluded given that these tests were not utilized in the clinical decision making process in this patient cohort. Similarly, BUN and Cr values that were below the reference range were excluded as low values for BUN or Cr do not necessitate clinical interventions.

Reported clinical intervention rates associated with abnormal postoperative chemistry panels were collected via manual electronic medical record chart review. The most common clinical interventions were considered and included oral or intravenous NaCl or KCl repletion, fluid restriction, Kayexalate/Kalexate (Sodium-Polystyrene Sulfonate), hemodialysis, intravenous fluid boluses (500-1000 mL), and nephrology consultation.

A linear mixed model regression analysis was used to determine significant associations between abnormal perioperative Na^+, K^+, BUN, Cr laboratory results and potential risk factors. Risk factors considered included preoperative chemistry panel results, type of surgery, age, gender, and specific Charlson Comorbidity Index (CCI) parameters [acquired immune deficiency syndrome, metastatic cancer, diabetes mellitus (DM) with and without end organ damage, moderate or severe renal disease, liver disease, peptic ulcer disease, chronic pulmonary disease (CPD), dementia, cerebrovascular disease (CVD), peripheral vascular disease (PVD), congestive heart failure (CHF), myocardial infarction (MI), and rheumatic disease].

Results

Demographics

After the initial review of the database, 1768 patients were identified. Following elimination of patients with incomplete data, 1,012 patients who underwent 764 (75.5%) primary aTSA and 248 (24.5%) RTA were included in the analysis. There were 447 (44.2%) males and 565 (55.8%) females with an average age of 67.6 (range: 18-94) and BMI of 29.7 (range: 12.1-59.1). The average Charlson Comorbidity index (CCI) was 3.8 (range: 0-8). Additional demographic information is summarized in Table 1.

Blood Chemistry

There was at least one abnormal chemistry panel result in 5.4% of patients preoperatively and in 25.6% of patients on POD1. The most common abnormal preoperative laboratory results were low sodium, high BUN, and high BUN/Cr (16.5%, 8.4%, and 61.5%, respectively). The factors associated with low preoperative sodium were male gender (OR=1.458, *P 0.039*) and renal disease (OR=2.103, *P=0.038*) [Table 2]. The factors associated with high preoperative BUN were older age (OR=1.083,

Table 1. Patient Demographics. BMI= Body Mass Index; Kg/m2 = kilograms per meter squared; LOS = Length of Stay; TSA = Total Shoulder Arthroplasty; RTSA = Reverse Total Shoulder Arthroplasty; CCI= Charleston Comorbidity Index

Demographic	Description
Total Cohort	1,012
Age Average [Range] (years)	67.6 [18-94]
Gender	
Male	447 (44.2%)
Female	565 (55.8%)
BMI Average [Range] (Kg/m^2)	29.7 [12.1-59.1]
Ethnicity	
White	927 (91.6%)
Black	56 (5.5%)
Other	29 (2.9%)
Type of Surgery	
TSA	764 (75.5%)
RTSA	248 (25.6%)
CCI Average [Range]	3.8 [0.0-8.0]

P<0.001) and patients with CVD (OR=10.488, *P=0.006*), DM (OR=3.796, *P<0.001*), malignancy (OR=6.085, *P=0.01*), or renal disease (OR=6.781, *P<0.001*) [Table 3]. The risk factors associated with preoperative elevated Cr were: male gender (OR=3.09, *P=0.01*), Diabetes Mellitus (OR=3.9, *P=0.005*), Diabetes Mellitus with end stage organ complications (OR=5.5, *P=0.03*), and Renal Disease (OR=38.02, *P<0.001*) [Table 4]. The only factor associated with high preoperative BUN/Cr ratio was older age (OR=1.036, *P=0.001*) [Table 5].

Similar to preoperatively, the most common abnormal postoperative labs were low sodium (17.0%; 170/999) and high BUN/Cr ratio (35.0%; 348/993). Risk factors associated with low postoperative sodium were CHF

Table 2. This table reports the factors that significantly increased the risk for abnormal preoperative sodium. CI = Confidence Interval; CHF = Congestive Heart Failure; DMCM = Diabetes Mellitus with end stage organ damage; PVD = Peripheral Vascular Disease; Na = sodium

Risk Factor	Preoperative Abnormal Sodium Risk Factors		
	Low		
	Odds Ratio	CI 95%	*P-value*
Male	1.458	1.019-2.804	0.039
Renal Disease	2.103	1.040-4.252	0.038
Risk Factor	**Postoperative Abnormal Sodium Risk Factors**		
	Low		
	Odds Ratio	CI 95%	*P-value*
CHF	1.377	1.103-43.411	0.039
DMCM	11.909	2.899-48.920	0.001
PVD	14.105	2.613-76.125	0.002
Low pre-op Na	516.825	238.416-1120.342	0.000

Table 3. This table reports the factors that significantly increased the risk of high preoperative (top) and postoperative (bottom) BUN. CI = Confidence Interval; CVD = Coronary Vascular Disease; DM = Diabetes Mellitus.

Risk Factor	Preoperative Abnormal High BUN Risk Factors		
	Preoperative		
	Odds Ratio	CI 95%	*P-value*
Age	1.083	1.045-1.124	0.000
CVD	10.488	1.941-56.686	0.006
DM	3.796	1.911-7.540	0.000
Malignancy	6.085	1.528-24.235	0.010
Renal disease	6.781	3.021-15.221	0.000
Risk Factor	**Postoperative Abnormal High BUN Risk Factors**		
	Odds Ratio	CI 95%	*P-value*
Male	2.553	0.999-6.520	0.050
DM	3.127	1.127-8.670	0.028
DMCM	12.330	2.308-65.874	0.003
Peptic ulcer disease	238.772	24.559-2321.479	0.000
Renal disease	3.709	1.187-11.587	0.024
High pre-op BUN	25.934	9.966-67.488	0.000

(OR=1.377, *P<0.05*), DMCM (OR=11.909, *P=0.001*), PVD (OR=14.105, *P=0.002*, and having a low preoperative sodium level (OR= 516.825, *P<0.001*) [Table 2]. Risk factors associated with high postoperative BUN/Cr ratio were age (OR=1.025, *P=0.01*, DM (OR=1.962, *P=0.0*1, and a high preoperative BUN/Cr ratio (OR=7.188, *P<0.001*) [Table 5].

Clinical Intervention for Abnormal Blood Chemistry

Although 25.6% (259/1,012) of patients had at least

Table 4. This table reports the risk factors that were significantly associated with elevated preoperative (top) and postoperative (bottom) creatinine values. CI = Confidence Interval; DM = Diabetes Mellitus; DMCM = Diabetes Mellitus with end stage organ damage; PVD = Peripheral Vascular Disease; Cr = Creatinine

Risk Factor	Preoperative Abnormal High Creatinine Risk Factors		
	Preoperative		
	Odds Ratio	CI 95%	*P-value*
Male	3.093	1.273-7.516	0.013
DM	3.851	1.512-9.812	0.005
DMCM	5.502	1.161-26.073	0.032
Renal disease	38.026	16.123-89.685	0.000
Risk Factor	**Postoperative Abnormal High Creatinine Risk Factors**		
	Odds Ratio	**CI 95%**	***P-value***
DM	7.548	1.328-42.912	0.023
DMCM	16.266	1.416-186.814	0.023
PVD	26.247	1.656-416.078	0.020
Renal disease	9.684	1.416-66.228	0.021
High pre-op Cr	174.656	23.365-1305.568	0.000

Table 5. This table reports the risk factors that were significantly associated with preoperative (top) and postoperative (bottom) abnormal BUN/Cr values. CI = Confidence Interval; DM = Diabetes Mellitus

Risk Factor	Preoperative Abnormal BUN/Cr Risk Factors		
	High		
	Odds Ratio	CI 95%	*P-value*
Age	1.036	1.019-1.052	0.000
Risk Factor	**Low**		
	Odds Ratio	**CI 95%**	***P-value***
Mild liver disease	114.928	7.966-1658.173	0.000
Renal disease	8.963	1.305-61.566	0.026
Risk Factor	**Postoperative Abnormal BUN/Cr Risk Factors**		
	High		
	Odds Ratio	**CI 95%**	***P-value***
Age	1.025	1.006-1.044	0.011
DM	1.962	1.177-3.270	0.010
High pre-op BUN/Cr	7.188	4.563-11.321	0.000
Risk Factor	**Low**		
	Odds Ratio	**CI 95%**	***P-value***
Low pre-op BUN/Cr	9.499	2.108-42.800	0.003

Table 6. Chemistry Panel Clinical Interventions. Clinical intervention rates for each abnormal chemistry panel parameter are reported by postoperative day 1 as well as for the total postoperative period. n = patient number; POD = postoperative da; IV= intravenous; mL = milliliters; CO2 = carbon dioxide; BUN= blood urea nitrogen; Cr = creatinine

Chemistry Panel Abnormality	Clinical Intervention	POD1 (n =1,012)	Total Postoperative Period
Hyponatremia	Sodium-Chloride Tab Fluid Restrictions	0.0%	0.0%
Hypokalemia	Potassium Chloride Tab IV Potassium Potassium Packet	3.5% 0.2% 0.0%	3.7%
Hyperkalemia	Calcium Carbonate/Gluconate Insulin Oral Glucose	7.7% 1.8% 0.0%	9.5%
BUN Cr	IV Fluid Bolus Nephrology Consultation	1.9%	1.9%
Total Clinical Intervention Rate			15.1%

one abnormal POD1 lab result, the total postoperative clinical intervention rate was 15.1% [Table 5]. Despite the relatively high incidence of low postoperative sodium (17%), there were no clinical interventions for hyponatremia. While the rates of postoperative hyperkalemia (3.3%, 33/999) and hypokalemia (4.4%, 44/999) were low, clinical intervention rates for hyper- and hypokalemia represented 87.4% of all interventions [Table 6]. Renal disease was the only significant risk factor for high postoperative potassium laboratory results (OR=9.071, *P=0.001*).

Discussion

Electrolyte imbalances if severe and untreated can manifest in devastating consequences such as cardiac arrhythmias, coma and sudden death; however, signs and symptoms are most often minor and nonspecific including: nausea, lethargy, muscle weakness or cramps, and headache (1). Fortunately, major complications of electrolyte imbalances, the most common being associated with hyponatremia and hypokalemia, are rare following aTSA and RTSA. A paper by Jiang et al. evaluated perioperative complications of aTSA and RTSA, reporting that the rates of acute mental status changes, stroke, myocardial infarction, ileus, and death to be less than 0.5% (4). Because these complications are rare but potentially devastating, it would be worthwhile to identify those patients deemed high-risk for developing electrolyte imbalances. In this study, renal disease was the risk factor most commonly associated with abnormal labs. This is not surprising given the kidney's major role in fluid balance and excretion (10). Renal impairment would result in abnormal markers of kidney function (BUN and creatinine) and electrolyte imbalances.

Despite the frequency of abnormal postoperative chemistry panel results (25.6%), a low clinical intervention rate was associated with these abnormalities. There are a number of possibilities for this discrepancy. First, a lab is considered abnormal even if the value is one point outside the normal range. Therefore, the number at which a lab is considered abnormal from a reference standpoint is not necessarily that which is clinically relevant and requires intervention (1). Second, each individual patient is distinct, and a lab value must be taken in the context of the patient's demographics and preexisting comorbidities (1, 11, 12). For example, as a result of natural aging, renal function declines, leading to elevated baseline BUN and creatinine (13). Especially over the age of 70, BUN increases to levels higher than those of creatinine, leading to an elevated BUN/Cr ratio (14-16). This could possibly have contributed to the high percentage of elevated BUN/Cr in our study. Fifty-one percent of the patients with high preoperative BUN/Cr ratios and 55% of those with high postoperative BUN/Cr ratios were at least 70 years of age. Finally, physical exam findings must also be taken into account (1, 11). An abnormal lab value may not be clinically significant if a patient is not showing symptoms of electrolyte imbalance For example, elevated BUN, Cr, or BUN/Cr ratio can signify dehydration; however, the patient may not be exhibiting any signs, making this lab finding clinically irrelevant (1, 18).

One of the most common risk factors for abnormal postoperative lab results was having that same abnormal lab preoperatively. This was true for hyponatremia, high BUN, elevated creatinine, and high and low BUN/Cr ratios. It is important to note that the Spearman's rho values showed strong association between preoperative and postoperative values, especially for sodium, potassium, and creatinine (0.885, 0.885, and 0.952, respectively). Given these findings, we recommend increased vigilance in ordering postoperative chemistry panels for those patients with abnormal preoperative chemistry results or patients with renal disease. These two risk factors alone captured 78.8% (204/259) of the abnormal postoperative laboratory results. Further study will

be necessary to assess the safety of eliminating routine laboratory testing for those patients without these risk factors.

This study has a several limitations. First, given that the study was retrospective, there were some inherent shortcomings in regard to data collection. We did not have access to the physician notes during the in-hospital period; therefore, it was not possible to have a full understanding of the decision-making process for each clinical situation. Additionally, some treatments can be used for multiple pathologies. For example, insulin can be administered for hyperglycemia or as a treatment for hyperkalemia. Due to the retrospective nature of this study, we were unable to determine the exact indication for each treatment, possibly leading to an overestimation of hyperkalemia intervention rates. Second, we searched for the most common clinical interventions that are used in the treatment of these electrolyte disturbances. It is possible that some physicians may have used less customary treatments. Third, because glucose values were excluded from analysis, the reported intervention rate may be less than at institutions that use the glucose value from the chemistry panel for proper glycemic control. Fourth, because this study evaluated patients from a single-institution with an average CCI of 0.6, it may not be representative of higher-risk patient populations at other surgical centers. Finally, though the sample size was relatively large, the event rates were small. This led to some risk factors having wide confidence intervals and potential for Type II error.

The purpose of this retrospective study was to analyze the utilization of the blood chemistry panel in the postoperative setting following aTSA and RTSA by identifying patients at risk for abnormal postoperative electrolytes and the associated clinical intervention rates. The most consistent and strongest risk factors for abnormal POD1 blood chemistry results were preoperative abnormal blood chemistry results and renal disease. Based on our data, these two groups of patients appear most appropriate for POD1 blood chemistry and routine POD blood chemistry in patients without these risk factors may be unnecessary.

Alexis A. Williams MD
Sidney Kimmel Medical College at Thomas Jefferson University, Department of Orthopaedics Surgery, Philadelphia, PA, USA

Eric H. Tischler BA
Daniel Sholder BS
Thema A. Nicholson MSc
Mitchell G. Maltenfort PhD
Charles Getz MD
Gerald Williams Jr MD
Surena Namdari MD MSc
The Rothman Institute, Thomas Jefferson University, 925 Chestnut St. 5th Floor, Philadelphia, PA, USA

References

1. Kraft MD, Btaiche IF, Sacks GS, Kudsk KA. Treatment of electrolyte disorders in adult patients in the intensive care unit. Am J Health Syst Pharm. 2005; 62(16):1663-82.
2. Tambe AA, Hill R, Livesley PJ. Post-operative hyponatraemia in orthopaedic injury. Injury. 2003; 34(4):253-5.
3. Anthony CA, Westermann RW, Gao Y, Pugely AJ, Wolf BR, Hettrich CM. What are risk factors for 30-day morbidity and transfusion in total shoulder arthroplasty? A review of 1922 cases. Clin Orthop Relat Res. 2015; 473(6):2099-105.
4. Jiang JJ, Toor AS, Shi LL, Koh JL. Analysis of perioperative complications in patients after total shoulder arthroplasty and reverse total shoulder arthroplasty. J Shoulder Elbow Surg. 2014; 23(12):1852-9.
5. Waterman BR, Dunn JC, Bader J, Urrea L, Schoenfeld AJ, Belmont PJ Jr. Thirty-day morbidity and mortality after elective total shoulder arthroplasty: patient-based and surgical risk factors. J Shoulder Elbow Surg. 2015; 24(1):24-30.
6. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg. 2010; 19(8):1115-20.
7. Freeborn DK, Baer D, Greenlick MR, Bailey JW. Determinants of medical care utilization: physicians' use of laboratory services. Am J Public Health. 1972; 62(6):846-53.
8. Schleicher E. The clinical chemistry laboratory: current status, problems and diagnostic prospects. Anal Bioanal Chem. 2006; 384(1):124-31.
9. Kreines A, McMillan S, Ford E, Dingle A. Reverse total shoulder arthroplasty for the treatment of synovial chondromatosis: a case report and review of the literature. Arch Bone Jt Surg. 2017; 5(2):117-20.
10. Epstein M. Aging and the kidney. J Am Soc Nephrol. 1996; 7(8):1106-22.
11. Murphy AM, Tunitsky-Bitton E, Krlin RM, Barber MD, Goldman HB. Utility of postoperative laboratory studies after female pelvic reconstructive surgery. Am J Obstet Gynecol. 2013; 209(4):363.e1-5.

12. Perrone RD, Madias NE, Levey AS. Serum creatinine as an index of renal function: new insights into old concepts. Clin Chem. 1992; 38(10):1933-53.
13. Kamath AF, McAuliffe CL, Kosseim LM, Pio F, Hume E. Malnutrition in joint arthroplasty: prospective study indicates risk of unplanned ICU admission. Arch Bone Jt Surg. 2016; 4(2):128-31.
14. Feinfeld DA, Bargouthi H, Niaz Q, Carvounis CP. Massive and disproportionate elevation of blood urea nitrogen in acute azotemia. Int Urol Nephrol. 2002; 34(1):143-5.
15. Stark JL. BUN/creatinine: your keys to kidney function. Nursing. 1980; 10(5):33-8.
16. Stookey JD, Pieper CF, Cohen HJ. Is the prevalence of dehydration among community-dwelling older adults really low? Informing current debate over the fluid recommendation for adults aged 70+years. Public Health Nutr. 2005; 8(8):1275-85.
17. Robinson BE, Weber H. Dehydration despite drinking: beyond the BUN/Creatinine ratio. J Am Med Dir Assoc. 2004; 5(2 Suppl):S67-71.
18. Thomas DR, Tariq SH, Makhdomm S, Haddad R, Moinuddin A. Physician misdiagnosis of dehydration in older adults. J Am Med Dir Assoc. 2004; 5(2 Suppl):S30-4.