Local Anesthetic Systemic Toxicity in Total Joint Arthroplasty Incidence and Risk Factors in the United States From the National Inpatient Sample 1998–2013

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Background: Local anesthetic systemic toxicity (LAST) is a rare and potentially devastating complication of regional anesthesia. Single-institution registries have reported a decreasing incidence, but these results have limited broad applicability. A recent study using a US database found a relatively high incidence of LAST. We used the National Inpatient Sample, a US database of inpatient admissions, to identify the national incidence and associated risk factors for LAST in total joint arthroplasties.

Methods: In this retrospective study, we studied patients undergoing hip, knee, or shoulder arthroplasty, from 1998 to 2013, with an adjunct peripheral nerve blockade. We used a multivariable logistic regression to identify patient conditions, hospital level variables, and procedure sites associated with LAST.

Results: A total of 710,327 discharges met inclusion criteria. The average adjusted incidence was 1.04 per 1000 peripheral nerve blocks, with decreasing trend over the 15-year study period (odds ratio [OR], 0.90; $P = 0.002$). Shoulder arthroplasty (OR, 4.35; $P = 0.0001$) compared with knee or hip arthroplasty and medium-size (OR, 3.34; $P = 0.003$) and large-size (OR, 2.40; $P = 0.025$) hospitals as compared with small hospitals were associated with increased odds of LAST.

Conclusions: The incidence of LAST nationally in total joint arthroplasty with adjunct nerve blocks is similar to recent estimates from academic centers, with a small decreasing trend through the study period. Despite an overall low incidence rate, practitioners should continue to maintain vigilance for manifestations of LAST, especially as the use of regional anesthesia continues to increase.

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Local anesthetic systemic toxicity (LAST) is a potentially devastating but rare complication of regional anesthesia. Estimating the frequency of LAST events in the context of peripheral nerve blocks (PNBs) is challenging because of their infrequent occurrence, as well as the range of their attendant clinical signs and symptoms

of LAST. Recent estimates demonstrate a low incidence and suggest a decreasing rate trend; however, most of these studies have been determined from regional anesthesia registries and single-institution quality improvement or billing queries, thus lacking generalizability to national practice.^{1–4} A recent study using a US database found the incidence of LAST was 1.8 per 1000 PNBs, noticeably higher than previous estimates.⁵ However, this study did not directly identify a diagnosis of LAST but used the presence of surrogate outcomes, such as a diagnosis of seizure, or cardiac arrest and administration of Intralipid (Baxter Healthcare Corporation, Deerfield, Illinois), to identify the incidence of LAST.⁵ The results lead to a question of whether improvements in technique, utilization of ultrasound guidance, and awareness of LAST have led to decreases in the rate of LAST in the United States.

We hypothesized that in total joint arthroplasties the incidence of LAST would be low with a decreasing trend. Furthermore, we determined differences in LAST incidence secondary to arthroplasty site, patient characteristics, and hospital factors such as location and bed size. To test our hypotheses, we searched the National Inpatient Sample (NIS) from 1998 to 2013 for LAST events in total joint arthroplasties of the hip, knee, and shoulder.

METHODS

Data Source

The NIS is an approximately 20% stratified survey of inpatient discharges in nonfederal hospitals in the United States.⁶ Because the NIS is such a large sample of discharges in the United States, it is ideal for studying low-frequency complications such as LAST.⁷ The NIS data are generated from discharge abstracts and include age, race, total charges, hospital characteristics including teaching status and location, discharge disposition, and up to 25 diagnostic and 15 procedural codes defined in the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*.⁸ The University of Chicago institutional review board exempted this research from review because there are no direct patient identifiers.

In 2012, the NIS was redesigned to improve national estimates, by sampling all participating hospitals rather than a subset.⁶ Secondary to the redesign, data from previous years (1998–2011) must be weighted appropriately to create accurate national estimates. The Agency for Healthcare Research and Quality provides updated discharge weights for years 1998 to 2011 to ensure accurate weighting of discharges prior to the redesign. We used these updated trend weights combined with the survey function for all patient-level analysis and regressions, as previously described.⁷

Data Classification

Our retrospective analysis used 2 methods to identify discharges that constituted the study population. The first used an

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ICD-9-CM procedure code for primary or revision arthroplasty of the hip, knee, and shoulder, and in the second, we used a cancelled surgical procedure code (V64.1, V64.3) with an admission diagnosis consistent with a total joint arthroplasty. Local anesthetic systemic toxicity complications including seizure and cardiac arrest may trigger postponement of the planned surgical procedure, but these patients should be included in the study population. Therefore, the second method identified this group of patients because they would be missed in the search for primary or revision arthroplasty. Discharges with a cancelled surgical procedure code that contained a nonarthroplasty orthopedic procedure were excluded from the study cohort. See Table, Supplemental Digital Content 1, <http://links.lww.com/AAP/A229>, for all ICD-9-CM codes used. The 2 sets of patients were combined for the calculation of incidence and complication rates.

Peripheral nerve blocks used as the primary anesthetic are not recorded in the NIS; however, PNBs not used as the primary anesthetic are recorded using ICD-9-CM codes (04.81). Arthroplasty patients with a procedure code for a PNB were included in the analysis.

A diagnosis of LAST was identified using 2 different ICD-9-CM codes with the presence of either indicating LAST: poisoning by peripheral nerve- and plexus-blocking anesthetics and unspecified local anesthetics (968.6, 968.9) or External Injury Codes for peripheral nerve- and plexus-blocking anesthetics and other unspecified local anesthetics causing adverse effects (E938.6, E938.9). External injury codes for local anesthetics identify adverse events when the correct drug and dose were properly administered but still led to an adverse effect.⁹ These codes are also unlikely to represent a nerve injury secondary to a PNB, as they would be represented by injury to peripheral nerve codes (995.0–9 and 996.0–9). External injury codes and poisoning codes have been previously utilized to evaluate national incidence of adverse drug effects in the Healthcare Cost and Utilization Project (HCUP) method series and for maternal complications from regional anesthesia during labor and delivery.^{9,10} In 2001, external injury codes were present in more than 85% of discharges with an injury diagnosis in NIS with a subsequent improvement in overall reporting to greater than 92% by 2012.¹¹

Manifestations of LAST were divided into 4 categories: neurological, cardiac major, cardiac minor, and unknown. Neurological included other convulsions (780.39); major cardiac complications included cardiac arrest (427.5), ventricular fibrillation (427.4), ventricular tachycardia (427.1), cardiac complications (arrest, insufficiency, failure) resulting from a procedure (997.1), and cardiopulmonary resuscitation (99.60, 99.63). A major complication of LAST occurred if a diagnosis of neurological, major cardiac, or a cancelled surgical procedure complication was present for that discharge record. Minor cardiac complications included other heart rhythms (427.9, 427.89). To prevent overestimation, discharges that included both major and minor cardiac diagnoses were included only in the major cardiac group. Discharges were classified as unknown if they did not contain an additional diagnosis consistent with known LAST complications.

Patient and Surgical Characteristics

Patient characteristics included age (years, categorical variable in quintiles), sex, type of admission (elective, emergent), and race (white, nonwhite, missing). Potential risk factors were identified prior to analysis based on previous case series, case reports, and a practice advisory as recommended in the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.¹² Risk factors included were cardiac (congestive heart failure, coronary artery disease, or other heart disease), pulmonary

(chronic obstructive pulmonary disease and asthma), renal (chronic kidney disease), neurological (late effects of cerebrovascular disease), hepatic (hepatitis and other liver diseases), and metabolic conditions (nutritional deficiencies, disorders of lipid metabolism, electrolyte and fluid disorders, other nutritional deficiencies, and endocrine and metabolic disorders). See Table, Supplemental Digital Content 2, <http://links.lww.com/AAP/A230>, for Clinical Classification Codes included to identify patient conditions.^{13–15} In addition, we identified hospital-level factors including hospital location and teaching status (rural, urban nonteaching, urban teaching), and hospital bed size (small, medium, large) as defined by HCUP.⁶

Statistical Analysis

The primary outcome was an ICD-9-CM diagnosis code for LAST during an admission for a total joint arthroplasty and a PNB for postoperative pain control. We utilized the Agency for Healthcare Research and Quality trend weights and the survey functions of STATA for all national estimates and regressions performed on the data, as described previously.⁷ Significant quantities of data were missing from race ($n = 113,554$ [16%]). Race was included in the univariable and multivariable regression by adding a missing category to each data element.

Patient characteristics for all procedures were compared from 1998 to 2013 using the national estimates and reported with 95% confidence intervals (CIs). The χ^2 test with a second-order Rao-Scott correction compared categorical variables. Comparison of the different incidence rates by procedure was performed using an adjusted Wald test.¹⁶ A temporal trend for LAST was determined using a multivariable logistic regression with year as a continuous independent variable.¹⁴ A univariable logistic regression was performed to test for a temporal trend in PNB utilization rates for all total joint arthroplasty sites. A univariate logistic regression was performed for independent variables including patient characteristics, procedure site, and hospital characteristics to identify covariates associated with LAST.⁶ Categorical variables were treated as nominal variables in the regression. $P < 0.10$ identified

FIGURE 1. Peripheral nerve block by procedure. The frequency of adjunct PNBs increased for all 3 procedures throughout the study period ($P = 0.0001$). Yearly utilization of PNBs was calculated as a percent of the total number of arthroplasty procedures performed by each surgical site and overall for each year. Peripheral nerve blocks in the NIS are recorded only when they are not used as the primary anesthetic. Hip indicates hip arthroplasty; Knee, knee arthroplasty; Shoulder, shoulder arthroplasty; Overall, combined frequency for all 3 procedures.

significant risk factors for inclusion in the multivariable logistic regression. $P < 0.05$ in the multivariable logistic regression was considered significant, and the odds ratio (OR), 95% CIs, and P values were reported.

A variance inflation factor of greater than 5 identified possible collinearity between predictors. Pearson goodness of fit assessed the multivariable model fit and was not significant at the 5% level ($P = 0.94$); thus, the multivariable model could not be rejected. STATA v14.0-MP (StataCorp, College Station, Texas) was used for all data analyses.

RESULTS

A total of 15,356,582 discharges were estimated to contain a procedure code or diagnosis consistent for total joint arthroplasty in the NIS between 1998 and 2013. A PNB procedure code was present in 710,327 discharges for an overall rate of 4.6%. Peripheral nerve block utilization increased through the study period for all arthroplasty procedure sites ($P = 0.0001$) (Fig. 1). Patient characteristics, procedure rates, and manifestations of LAST are presented in Table 1.

TABLE 1. Characteristics of Patients With and Without LAST and OR From a Univariable Logistic Regression

	LAST, n	No LAST, n	OR (95% CI)	P
All patients	737	709,590		
Age				
<57 y	124 (16.8)	159,032 (22.4)	Reference	
58–65 y	153 (20.8)	176,040 (24.8)	1.11 (0.65–1.92)	0.698
66–72 y	174 (23.6)	171,812 (24.2)	1.29 (0.77–2.17)	0.330
73–78 y	159 (21.6)	114,906 (16.2)	1.77 (1.02–3.07)	0.041
>78 y	126 (17.1)	87,640 (12.4)	1.83 (1.03–3.27)	0.040
Sex				
Male	227 (30.8)	272,242 (38.4)	Reference	
Female	510 (69.2)	436,958 (61.6)	1.40 (0.94–2.09)	0.095
Race				
White	530 (71.9)	518,306 (73.0)	Reference	
Nonwhite	86 (11.7)	77,850 (11.0)	1.08 (0.65–1.79)	0.765
Missing	121 (16.4)	113,434 (16.0)	1.04 (0.65–1.67)	0.875
Chronic conditions				
Cardiac	164 (22.3)	112,174 (15.8)	1.53 (1.04–2.24)	0.029
Pulmonary	132 (17.9)	106,109 (15.0)	1.25 (0.81–1.91)	0.314
Renal	30 (4.1)	26,139 (3.7)	1.10 (0.48–2.54)	0.819
Neurological	<10 (<1.4)	4031 (0.6)	1.25 (0.16–9.45)	0.830
Hepatic	12 (1.6)	10,350 (1.5)	1.12 (0.26–4.82)	0.874
Metabolic	435 (59.0)	391,294 (55.1)	1.17 (0.82–1.67)	0.382
Type of admission				
Elective	654 (88.7)	659,565 (93.0)	0.57 (0.32–1.05)	0.070
Emergent	62 (8.4)	35,821 (5.0)	Reference	
Missing	21 (2.8)	14,203 (2.0)	0.84 (0.23–3.11)	0.796
Procedure site				
Hip	45 (6.1)	47,986 (6.7)	Reference	
Knee	433 (58.8)	601,233 (84.7)	0.77 (0.36–1.66)	0.508
Shoulder	259 (35.1)	60,371 (8.5)	4.61 (2.05–10.4)	0.0001
Hospital location and teaching				
Urban teaching	315 (42.7)	346,134 (48.8)	Reference	
Urban nonteaching	315 (42.7)	274,307 (38.7)	1.26 (0.82–1.94)	0.287
Rural	107 (14.5)	85,719 (12.1)	1.38 (0.77–2.46)	0.281
Hospital bed size				
Large	434 (58.9)	391,655 (55.2)	2.91 (1.35–6.30)	0.007
Medium	254 (34.5)	185,480 (26.1)	3.59 (1.62–7.95)	0.002
Small	49 (6.6)	129,024 (18.2)	Reference	

Results are nationwide estimates. Numbers are presented as count estimates or means with percentages in parentheses and respective 95% CIs when indicated. Results less than 10 cannot be reported due to the Agency for Healthcare Research and Quality regulations. “Nonwhite” race category includes Black, Hispanic, Native American, Asian and Pacific Islander, and Other. Hospital bed size, location, and teaching status are based on NIS HCUP categories.

Chronic conditions were identified as risk factors, including more specifically: cardiac (congestive heart failure, coronary artery disease or other heart disease), pulmonary (chronic obstructive pulmonary disease and asthma), renal (chronic kidney disease), neurological (late effects of cerebrovascular disease), hepatic (hepatitis and other liver diseases) and metabolic conditions (nutritional deficiencies, disorders of lipid metabolism, electrolyte and fluid disorders, other nutritional deficiencies, endocrine and metabolic disorders).

TABLE 2. Mean Incidence of LAST and LAST With Known Major Complications per 1000 PNBs by Procedure Type and Overall

	Mean LAST Incidence (95% CI)	Mean LAST Incidence With Documented Major Complications (95% CI)
Hip	0.93 (0.21–1.65)	0.10 (0.0–0.33)
Knee	0.72 (0.54–0.90)	0.13 (0.06–0.20)
Shoulder	4.27* (2.87–5.67)	1.15* (0.49–1.80)
Overall	1.04 (0.49–1.80)	0.22 (0.13–0.30)

Shoulder arthroplasty had a higher incidence of LAST and LAST with major complications as compared with both knee and hip arthroplasty. A major complication of LAST includes a diagnosis of neurological, major cardiac, or a cancelled surgical procedure complication in the discharge record. Comparison of the different incidence rates by procedure was performed using an adjusted Wald test.

*Significant value, $P < 0.005$.

A diagnosis code for LAST was present in 737 discharges for an overall incidence of 1.04 per 1000 PNBs (CI, 0.49–1.80) (Table 2). The incidence of LAST was highest in shoulder arthroplasty, 4.27 per 1000 PNBs (CI, 2.87–5.67), than in hip 0.93 per 1000 (CI, 0.21–1.65) or knee arthroplasty 0.72 per 1000 (CI, 0.54–0.90) ($P = 0.0001$) (Table 2, Fig. 2). External-cause-of-injury codes (E938.6 and E938.9) were the identifying codes for a diagnosis of LAST in 99% of the discharges as compared with the poisoning diagnostic codes (968.6 and 968.9).

The incidence of LAST with documented major complications was 0.22 per 1000 PNBs (CI, 0.13–0.30) (Fig. 3). Major

FIGURE 3. Major LAST complications by procedure. Shoulder arthroplasty had the highest yearly frequency of LAST with major complications with a spike in frequency seen in 2003 and 2007. The frequency of LAST with major complications was calculated by dividing the number of diagnoses with major complications by the total number of arthroplasty procedures performed with a PNB, for each procedure site and overall. Hip indicates hip arthroplasty; Knee, knee arthroplasty; Shoulder, shoulder arthroplasty; Overall, combined frequency for all 3 procedures.

complications were documented in 21% (157/737) of patients with LAST, and types of complications can be seen in Table 3. The most common major complication was convulsions, 8.1% (60/737), followed by major cardiac complications in 6.8% (50/737). A postponed surgical procedure code was present in 12.5% of

FIGURE 2. A–D, Overall LAST incidence by procedure site. Shoulder arthroplasty demonstrated the highest yearly frequency of overall diagnoses of LAST with 2 spikes in events noted from 2001 to 2002 and 2007, followed by a decreasing trend ($P = 0.002$). The frequency of yearly LAST was calculated by dividing the number of diagnoses by the total number of arthroplasty procedures performed with a PNB, for each procedure site and overall. A, Shoulder arthroplasty. B, Knee arthroplasty. C, Hip arthroplasty. D, All procedures combined.

TABLE 3. Manifestations of LAST

Manifestations	LAST, n (%)	No LAST, n (%)	P
Cardiac major			
Cardiac arrest/cardiopulmonary resuscitation	17 (2.3)	437 (0.06)	0.0001
Arrhythmia	27 (3.7)	1360 (0.19)	0.0001
Cardiac complications	10 (1.4)	3838 (0.54)	0.201
Overall	50 (6.8)	5304 (1.2)	0.0001
Cardiac minor			
Other cardiac dysrhythmia	32 (4.3)	20,488 (0.74)	0.2705
Convulsions	60 (8.1)	2383 (0.34)	0.0001
Cancelled surgical procedure	92 (12.5)	900 (0.13)	0.0001
Unknown	566 (76.7)	681,998 (96.1)	0.0001

Discharges containing a diagnosis of LAST had higher rates of major complications as compared with the general arthroplasty cohort with a PNB without a diagnosis of LAST ($P = 0.0001$). Manifestations of LAST were divided into 4 categories: cardiac major, cardiac minor, neurological, and unknown. Major cardiac complications included cardiac arrest and cardiopulmonary resuscitation, arrhythmia (ventricular fibrillation, ventricular tachycardia), and cardiac complications (arrest, insufficiency, failure) resulting from a procedure. Neurological complications were convulsions. To prevent overestimation, patients who exhibited both major and minor cardiac symptoms were included only in the major cardiac group. Patients with a diagnosis of LAST without any of the above diagnosis were characterized as unknown manifestations.

discharges containing a diagnosis of LAST (92/737). Discharges containing a diagnosis of LAST had higher rates of major complications as compared with discharges without a diagnosis of LAST ($P = 0.0001$). Mortality associated with a diagnosis of LAST was 0% and did not differ from discharges without a diagnosis of LAST (0.07%) ($P = 0.794$).

A univariable analysis is presented in Table 1, and multivariable analysis is presented in Table 4. In the multivariable analysis, the yearly trend of odds of LAST decreased during the study period by 10% per year (OR, 0.90; CI, 0.84–0.96; $P = 0.002$). Shoulder arthroplasty (OR, 4.35; CI, 1.96–9.65; $P = 0.0001$) had a higher odds of LAST as compared with hip or knee arthroplasty. Hospital factors associated with an increased odds of LAST included large-size (OR, 2.40; CI, 1.12–5.15; $P = 0.025$) and medium-size (OR, 3.34; CI, 1.52–7.33; $P = 0.003$) hospitals compared with small hospitals; however, teaching status and urban/rural location were not significant. Furthermore, age or patient medical conditions did not increase the odds of LAST in the multivariable analysis.

DISCUSSION

In our study of a large nationally representative database, we identified an estimated LAST incidence of 1.04 per 1000 PNBs and documented major LAST complications were present in 0.22 per 1000 PNBs. Furthermore, the odds of a diagnosis of LAST decreased throughout the study period. Risk factors associated with increased odds of LAST are shoulder arthroplasty as compared with knee and hip arthroplasty, and large- and medium-size hospitals as compared with small hospitals.

Our estimate of the national incidence of LAST is similar to recent single-institution, large academic center estimates demonstrating a low baseline incidence of LAST with a decreasing trend. Recent registry and single-institution analyses have estimated the

incidence of LAST between 0.87 per 1000 PNBs and 0.04 per 1000 PNBs with the primary source of variation between studies due to different criteria for what constitutes a diagnosis of LAST.^{1–4,17} For example, the Australian and New Zealand Registry of Regional Anesthesia identified an incidence of 0.87 per 1000 PNBs but included generalized central nervous system excitation as a criterion for LAST in addition to seizure and cardiac arrest.³ Alternatively, Liu et al⁴ limited LAST criteria to seizure and cardiac arrest and reported a LAST incidence of 0.04 per 1000 PNBs and no cardiac arrests. Thus, we reported the rates of LAST with major complications and the overall incidence in the NIS.

Variation in our study between the incidence of LAST with major complications and LAST with unknown complications may be secondary to the ICD-9-CM codes used to identify an adverse or toxic effect from local anesthetics. The etiology of the complication dictates which ICD-9-CM code is applied, as adverse effects codes (E938.6, E938.9) apply when the local anesthetic was correctly prescribed and properly administered yet resulted in toxic effects, whereas poisoning (968.6, 968.9) apply when an error occurred and an unintended overdose of local anesthetic was administered.⁸ Adverse event codes should be associated with the specific manifestation of the effect such as seizure or arrhythmia; however, because adverse event codes are not required for reimbursement, additional diagnoses related to the complication may not have been coded for and led to the unknown category. Thus, the incidence of major complications may be underestimated by our method.

Our incidence of LAST with major complications is lower than that in a recent study by Morwald et al,¹⁸ also using a large nationally representative administrative database. Morwald et al¹⁸

TABLE 4. Multivariable Logistic Regression of Patient, Hospital, and Procedure Variables for Discharges Containing a Diagnosis of LAST

	OR (95% CI)	P
Year	0.90 (0.84–0.96)	0.002
Elective		
Emergent	Reference	
Elective	0.81 (0.45–1.46)	0.484
Missing	0.28 (0.07–1.12)	0.073
Age		
<57 y	Reference	
58–65 y	1.15 (0.66–2.01)	0.616
66–72 y	1.21 (0.71–2.05)	0.477
73–78 y	1.47 (0.84–2.59)	0.180
>78 y	1.40 (0.78–2.53)	0.261
Chronic conditions		
Cardiac	1.40 (0.94–2.09)	0.101
Procedure type		
Hip	Reference	
Knee	0.75 (0.36–1.59)	0.452
Shoulder	4.35 (1.96–9.65)	0.0001
Hospital bed size		
Small	Reference	
Medium	3.34 (1.52–7.33)	0.003
Large	2.40 (1.12–5.15)	0.025

A decreasing trend in a diagnosis of LAST is seen in addition to increased risk of upper-extremity PNBs as compared with lower-extremity nerve blocks. Hospital bed size is based on NIS HCUP categories.

identified an incidence of 1.8 per 1000 PNBs for total joint arthroplasties; however, a diagnosis of LAST was not identified directly using *ICD-9-CM* codes. Rather, a LAST diagnosis was identified in patients with a PNB if they experienced a major complication, such as cardiac arrest, Intralipid administration, or seizure. Despite the differences in our methods, both studies identify a surprisingly high frequency of major LAST complications around the year 2007, most notably with shoulder arthroplasty, followed by a steady decrease. An increase in PNBs is also seen around the same period, and the increase in LAST frequency may be associated with an expansion of regional anesthesia practice, although this theory is speculative. Overall, our rates of major complications seem consistent with other recent single-institution and registry studies.

Peripheral nerve blocks associated with shoulder arthroplasty had the highest odds of LAST as compared with hip and knee arthroplasty. Reasons for this disparity include higher blood concentrations of local anesthetic in brachial plexus blocks than femoral/sciatic blocks and proximity of the vasculature to the central nervous system.^{19,20} Our results seem consistent with previous studies reporting a higher incidence of LAST in patients undergoing upper-extremity blocks.^{3,20} Further research is needed to confirm this finding and understand the mechanism for this difference.

Surprisingly, mortality was not increased in discharges containing a diagnosis of LAST. Mortality rates from case reviews estimated mortality from LAST between 1.1% and 10%, and an analysis of closed claims involving LAST showed 37% (7/19) of cases involved brain damage or death.^{13,14,21} Mortality estimates from case studies may be influenced by publication bias and may not accurately reflect the mortality from complications of LAST; thus, mortality from LAST may be lower than previously thought. In our analysis, there were 50 discharges (6.8%) with LAST containing major cardiac complications; thus, we expected a higher mortality rate than was observed. Our analysis was unable to identify if Intralipid had any impact on mitigating the mortality from LAST.

Our study has several limitations. The NIS consists of information from discharge abstracts, and no relevant information pertaining to the type of block performed, amount and type of local anesthetic used, block technique, or any other information pertaining to the PNB is contained in the data set. Therefore, our analysis cannot make any conclusions regarding PNB-specific risk factors as they relate to LAST. In addition, the NIS does not contain Current Procedural Terminology codes, and thus our cohort consisted of PNBs that were performed not as the primary anesthetic. Our results may not be generalizable to patients who undergo PNBs as the primary anesthetic because factors influencing the block may be different.

The accuracy of coding for a diagnosis of LAST is unknown in administrative databases, such as the NIS. Errors in diagnosis coding can occur at the physician level or data abstraction level. Physician errors are added to the analysis by an inappropriate diagnosis on the chart, utilizing the wrong terminology for a diagnosis or omitting a diagnosis from the chart. Errors from medical coders occur when they misinterpret the chart and make incorrect decisions about which diagnosis to code for or to omit. Local anesthetic systemic toxicity is a rare event and as such may be more susceptible to inappropriate *ICD-9-CM* coding as for malignant hyperthermia.²² Furthermore, in our study, most discharges with a diagnosis of LAST were classified as unknown and did not contain an associated manifestation of LAST such as seizure or cardiac complication. However, previous studies have used these *ICD-9-CM* codes to identify a diagnosis of LAST.^{10,23} In addition, rates of LAST complications were significantly higher in the LAST cohort as compared with the general PNB cohort. Despite these limitations, the NIS provides an opportunity to identify

nationally representative incidence rates of LAST in the setting of total joint arthroplasty.

We identified the incidence of LAST as 1.04 per 1000 PNBs, with a trend indicating a decreasing incidence. Local anesthetic systemic toxicity continues to persist as a rare, clinically relevant complication of PNB that remains more common than other recent academic estimates suggest. Our analysis identified risk factors for LAST including shoulder arthroplasty and large and medium hospital size. Future studies should test our findings through the use of other nationally representative databases in addition to identifying complications of PNBs using electronic medical records.

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