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ASA Classification as a Risk Stratification Tool in Adult Spinal Deformity Surgery: A Study of 5805 Patients

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Abstract

Study Design: Retrospective analysis of prospectively collected data.

Objectives: Adult spinal deformity (ASD) surgery is a highly complex procedure that has high complication rates. Risk stratification tools can improve patient management and may lower complication rates and associated costs. The goal of this study was to identify the independent association between American Society of Anesthesiologists (ASA) class and postoperative outcomes following ASD surgery.

Methods: The 2010-2014 American College of Surgeons National Surgical Quality Improvement Program database was queried using Current Procedural Terminology and International Classification of Diseases, Ninth Revision, codes relevant to ASD surgery. Patients were divided based on their ASA classification. Bivariate and multivariate logistic regression analyses were employed to quantify the increased risk of 30-day postoperative complications for patients with increased ASA scores.

Results: A total of 5805 patients met the inclusion criteria, 2718 (46.8%) of which were ASA class I-II and 3087 (53.2%) were ASA class III-IV. Multivariate logistic regression revealed ASA class to be a significant risk factor for mortality (odds ratio [OR] = 21.0), reoperation within 30 days (OR = 1.6), length of stay ≥5 days (OR = 1.7), overall morbidity (OR = 1.4), wound complications (OR = 1.8), pulmonary complications (OR = 2.3), cardiac complications (OR = 3.7), intra-/postoperative red blood cell transfusion (OR = 1.3), postoperative sepsis (OR = 2.7), and urinary tract infection (OR = 1.6).

Conclusions: This is the first study evaluating the role of ASA class in ASD surgery with a large patient database. Use of ASA class as a metric for preoperative health was verified and the association of ASA class with postoperative morbidity and mortality in ASD surgery suggests its utility in refining the risk stratification profile and improving preoperative patient counseling for those individuals undergoing ASD surgery.

Keywords

adult spinal deformity surgery, ASA class, American Society of Anesthesiologists, risk stratification, complications, outcomes

Introduction

As the elderly population in the United States continues to rise and is projected to nearly double by 2050,[1] adult spinal deformity (ASD) is becoming increasingly prevalent. The United States Bone and Joint Initiative estimates a total of $75.8 billion in hospital discharge costs related to spinal deformity disorders, with 65% of that cost being derived from scoliosis, spondylolisthesis, and other spondylopathies.[2] Additionally, conservative estimates of complications from ASD surgery tally to $5.4 billion, with complication rates ranging from 13% to 59%.[3] Although there are continued developments in techniques, instrumentation, and anesthesia in the realm of ASD surgery,[3,4] the increasing emphasis on cost containment and restructuring of compensation schemes have prioritized the

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Table 1. Prior Literature Overview for ASA Class Utility in ASD Surgery.

Authors	Year	Data Source	Sample Size	ASA Class Analyzed	Major Findings
Pateder et al[17]	2008	Single-center, chart review	361	Yes	ASA + for short-term mortality
Schwab et al[14]	2012	Multicenter, chart review	953 (150 used)	Yes	ASA not correlated with postoperative complications
Tang et al[7,a]	2014	Single-center, chart review	236	Yes	ASA + for major postoperative complications (OR = 2.21)
Smith et al[16]	2016	Multicenter, prospective	291	No	Comorbidities, age, and obesity associated with complications
Manoharan et al[28]	2016	Multicenter, database	747	No	Preoperative risk factors associated with 30-day readmissions
This study	2016	Multicenter, database	5822	Yes	ASA + for postoperative morbidity

Abbreviations: ASA, American Society for Anesthesiologists; ASD, adult spinal deformity; OR, odds ratio.
[a]Evaluated for lumbar scoliosis surgery only.

utility of potential risk stratification tools to predict complications and improve perioperative planning and management.

The American Society of Anesthesiologists (ASA) Physical Status classification system was originally developed as a variable for statistical tabulations.[5] The original goal of the ASA class system was to assess overall preoperative physical status of the patient and not surgical risk per se because it does not include the impact of surgery on the patient's outcomes. However, since then, multiple studies have demonstrated and emphasized its potential as a useful proxy for judging patients' operative risk and as a predictor for postoperative complications, particularly in spinal surgeries.[6-13] Because the score is assigned preoperatively based on the patient's preoperative health, ASA classifications have the potential to be an accessible tool for surgeons to gauge patient risk for postoperative complications.

Prior literature exploring the utility of preoperative factors, especially ASA class, in ASD surgery has conflicting results (Table 1). Schwab et al conducted a multicenter, retrospective study of ASD patients and found no significant differences in ASA class between the cohorts with complications and without complications.[14] However, Tang et al identified ASA class to be an independent risk factor for major complications in ASD surgery, while Pateder et al also found an association between a higher ASA class ranking and patient mortality. This study seeks to help resolve these conflicts from previous works by investigating the capability of ASA class to predict adverse postoperative events using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database.

Materials and Methods

This was a retrospective study of prospectively collected data in the 2010-2014 ACS-NSQIP database. NSQIP is a large national database with risk-adjusted 30-day postoperative morbidity and mortality outcomes. More than 500 hospitals that vary in size, socioeconomic location, and academic affiliation contributed data to the 2010-2014 ACS-NSQIP database.[15] NSQIP data is collected prospectively by dedicated clinical abstractors at each institution on more than 150 demographic, preoperative, intraoperative, and 30-day postoperative variables. These on-site surgical clinical reviewers stringently maintain the fidelity of the NSQIP database, and they conduct ongoing internal auditing processes to analyze interrater reliability and to ensure accuracy of data collection.

Inclusion Criteria

The NSQIP database from 2010 to 2014 was used in this study. Adult patients (≥18 years) undergoing spinal fusion for deformity were identified based on Current Procedural Terminology (CPT) codes 22 800, 22 802, 22 804, 22 808, 22 810, 22 812, 22 818, and 22 819. CPT codes 22 843, 22 844, 22 846, or 22 847 were also included to capture long, multilevel fusion constructs. Patients with CPT codes 22 842 and 22 845 were included if they had an ICD-9 (International Classification of Diseases, Ninth Revision) diagnosis for spinal deformity (including 737.1, 737.2, 737.3, 737.4, 737.8, and 737.9). Cases with missing preoperative data; emergency cases; patients with a wound class of 2, 3, or 4; an open wound on their body; current sepsis; current pneumonia; prior surgeries within 30 days; cases requiring cardiopulmonary resuscitation prior to surgery; any patients undergoing a nonelective procedure; or cases with diagnoses of cervical spine, trauma or injury to spine, or neoplasm of spine were excluded in order to reduce the risk of confounding variables.

Variable Definition

Patient demographic variables included sex, age (≥65 years old), and race (white, black, Hispanic, and other). Other race included American Indian, Alaska Native, Asian, Native Hawaiian, Pacific Islander, or unknown/not reported. Preoperative variables included operation year, obesity (body mass index ≥30 kg/m^2), diabetes (non–insulin-dependent diabetes mellitus or insulin-dependent diabetes mellitus), current smoking (within 1 year of surgery), dyspnea (≤30 days prior to surgery), functional status prior to surgery (independent or dependent/partially dependent ≤30 days prior to surgery), pulmonary comorbidity (ventilator dependent ≤48 hours prior to surgery or history of chronic obstructive pulmonary disease ≤30 days prior to surgery), cardiac comorbidity (use of hypertensive medication or history of chronic heart failure ≤30 days prior to surgery), renal comorbidity (acute renal failure ≤24 hours prior to surgery or dialysis treatment ≤2 weeks prior to surgery), steroid use for chronic condition (≤30 days prior to surgery), ≥10% loss of body weight (in the last 6 months), bleeding disorder (chronic, active condition), and preoperative transfusion of ≥1 unit of whole/packed red blood cells (RBCs; ≤72 hours prior to surgery).

Intraoperative variables included fusion length (long fusion is ≥4 levels during an anterior approach and ≥7 levels during a posterior approach), surgical approach (posterior, anterior, or combined), bone graft, fusion to pelvis, osteotomy, operative time (≥4 hours), and total relative value units. Thirty-day postoperative outcome variables include mortality, any postoperative complication, length of stay (LOS; ≥5 days), wound complication (superficial or deep surgical site infection, organ space infection, or wound dehiscence), pulmonary complication (pneumonia, unplanned reintubation, or duration of ventilator-assisted respiration ≥48 hours), venous thromboembolism (pulmonary embolism or deep vein thrombosis), renal complication (progressive renal insufficiency or acute renal failure), urinary tract infection (UTI), peripheral nerve injury, cardiac complication (cardiac arrest requiring cardiopulmonary resuscitation or myocardial infarction), intra-/postoperative transfusion, sepsis, central nervous system complication (cerebrovascular accident or coma), reoperation (related to initial procedure), and unplanned readmission (related to initial procedure). ACS-NSQIP provides further information on variable characteristics.[16]

Patients were split up into 4 cohorts according to their assigned ASA classification score of 1, 2, 3, and 4. Exclusion criteria discussed above removed any instances of ASA classes 5 or 6 and so was not considered.

Statistical Analysis

Bivariate analyses were performed on patient demographic, preoperative, intraoperative, and postoperative characteristics using Pearson's χ^2 test. Fischer's exact test was used where appropriate. Multivariable logistic regression analysis, with stepwise entry and removal criteria set to a significance level of .05, was performed to identify postoperative outcomes with which the higher ASA classes were associated. The *c*-statistic, which is the area under the receiver operating characteristic curve, was also retrieved from the predictors of postoperative outcomes models and determined the accuracy of this model. The area under this curve measures the ability of the model to correctly classify those with the complication and those without. SAS Studio Version 3.4 (SAS Institute Inc, Cary, NC) was used for all statistical analysis.

Results

Study Population

A total of 5803 patients met the inclusion criteria for the study, of which 155 (2.7%) patients were ASA class I, 2561 (44.1%) patients were ASA class II, 2927 (50.4%) patients were ASA class III, and 160 (2.8%) patients were ASA class IV (Table 2). Patients with ASA class IV were more likely to be male, ≥65 years of age, black, obese, diabetic, dyspneic, partially or totally functionally dependent, pulmonary comorbid, cardiac comorbid, renal comorbid, smokers, use steroids, have recent weight loss, bleeding disorder, longer operation times, osteotomy, fusion to pelvis, longer fusion lengths, and posterior surgical approach.

Unadjusted Analysis

There were statistically significant differences in 30-day unadjusted morbidities and mortality between the 4 ASA cohorts (Table 3). Patients in the ASA IV cohort, compared to the ASA I cohort, experienced a higher rate of mortality (3.8% vs 0.0%), any complication (51.9% vs 17.4%), LOS ≥5 days (55.0% vs 20.6%), wound complication (4.4% vs 0.6%, $P = .0005$), pulmonary complication (11.9% vs 0.6%), UTI (3.1% vs 0.6%, $P = .0095$), cardiac complication (4.4% vs 0.0%), intra-/postoperative RBC transfusion (41.3% vs 15.5%), sepsis (6.3% vs 0.0%), reoperation (9.6% vs 0.7%), and unplanned readmission (12.3% vs 3.5%). All *P* values are <.0001 unless otherwise stated.

Subgroup Analysis Between ASA Class II and III

A bivariate subgroup analysis was performed between ASA class II and ASA class III (Table 4). Patients in the ASA class III cohort were more likely to be ≥65 years of age, obese, diabetic, dyspneic, partially or totally functionally dependent, pulmonary comorbid, cardiac comorbid, renal comorbid, use steroids, have recent weight loss, bleeding disorder, operation time ≥4 hours, osteotomy, fusion to pelvis, longer fusion lengths, and posterior surgical approaches.

There were statistically significant differences in 30-day unadjusted morbidities and mortality between the ASA II and ASA III cohorts (Table 5). ASA III patients experienced a higher rate of mortality (0.8% vs 0.0%), any complication (36.8% vs 24.8%), LOS ≥5 days (34.6% vs 21.2%), wound complication (3.2% vs 1.6%, $P = .0001$), pulmonary complication (3.4% vs 1.6%), renal complication (1.4% vs 0.6%), UTI (2.7% vs 1.4%, $P = .0010$), peripheral nerve injury (0.2% vs 0.0%, $P = .0364$), cardiac complication (0.9% vs 0.2%, $P = .0015$), intra-/postoperative RBC transfusion (31.7% vs 21.7%), sepsis (2.4% vs 0.9%), reoperation (4.9% vs 2.9%, $P = .0003$), and unplanned readmission (7.8% vs 4.2%). All *P* are <.0001 unless otherwise stated.

Multivariate Analysis

Multivariate logistic regression analysis (Table 6) revealed ASA classes II, III, and IV, compared to ASA class I, to be a significant, independent risk factor for several acute

Table 2. Patient Demographics, Comorbidities, and Intraoperative Variables (N = 5803).[a]

	ASA Class I		ASA Class II		ASA Class III		ASA Class IV		
Category	n	%	N	%	n	%	n	%	*P* Value
Sex									
Female	87	56.1%	1547	60.4%	1719	58.7%	70	43.8%	**.0006**
Male	68	43.9%	1014	39.6%	1208	41.3%	90	56.3%	
Age ≥65 years	17	11.0%	782	30.5%	1423	48.6%	93	58.1%	**<.0001**
Race									
White	123	79.4%	2093	81.7%	2374	81.1%	121	75.6%	**.0458**
Other	19	12.3%	201	7.8%	203	6.9%	9	5.6%	
Hispanic	5	3.2%	93	3.6%	110	3.8%	11	6.9%	
Black	8	5.2%	174	6.8%	240	8.2%	19	11.9%	
Obese	28	18.1%	919	35.9%	1421	48.5%	71	44.4%	**<.0001**
Diabetes	4	2.6%	161	6.3%	627	21.4%	58	36.3%	**<.0001**
Dyspnea	1	0.6%	86	3.4%	233	8.0%	26	16.3%	**<.0001**
Partially or totally functionally dependent	0	0.0%	60	2.3%	177	6.0%	27	16.9%	**<.0001**
Pulmonary comorbidity	0	0.0%	53	2.1%	211	7.2%	29	18.1%	**<.0001**
Cardiac comorbidity	7	4.5%	1081	42.2%	1956	66.8%	118	73.8%	**<.0001**
Renal comorbidity	0	0.0%	2	0.1%	14	0.5%	9	5.6%	**<.0001**
Smoke	24	15.5%	523	20.4%	621	21.2%	38	23.8%	.2801
Steroid use	1	0.6%	48	1.9%	146	5.0%	24	15.0%	**<.0001**
Recent weight loss	0	0.0%	0	0.0%	10	0.3%	1	0.6%	**.0350**
Bleeding disorder	2	1.3%	14	0.5%	48	1.6%	6	3.8%	**.0001**
Preoperative RBC transfusion	0	0.0%	3	0.1%	10	0.3%	0	0.0%	.4290
Operation time quartile									
Q1 (≤154 minutes)	38	24.5%	774	30.2%	610	20.8%	29	18.1%	**<.0001**
Q2 (≤235 minutes)	48	31.0%	645	25.2%	737	25.2%	33	20.6%	
Q3 (≤346 minutes)	31	20.0%	607	23.7%	755	25.8%	49	30.6%	
Q4 (>346 minutes)	38	24.5%	535	20.9%	825	28.2%	49	30.6%	
Operation year									
2010	12	7.7%	220	8.6%	221	7.6%	14	8.8%	**.0005**
2011	14	9.0%	146	5.7%	185	6.3%	15	9.4%	
2012	12	7.7%	178	7.0%	218	7.4%	16	10.0%	
2013	52	33.5%	957	37.4%	1041	35.6%	63	39.4%	
2014	65	41.9%	1060	41.4%	1262	43.1%	52	32.5%	
Osteotomy	17	11.0%	325	12.7%	474	16.2%	21	13.1%	**.0016**
Fusion to pelvis	1	0.6%	165	6.4%	305	10.4%	11	6.9%	**<.0001**
Fusion length									
Long	83	53.5%	1522	59.4%	1931	66.0%	123	76.9%	**<.0001**
Short	72	46.5%	1039	40.6%	996	34.0%	37	23.1%	
Surgical approach									
Posterior	85	54.8%	1272	49.7%	1827	62.4%	107	66.9%	**<.0001**
Anterior	65	41.9%	1177	46.0%	1009	34.5%	46	28.8%	
Combined	5	3.2%	112	4.4%	91	3.1%	7	4.4%	

Abbreviations: ASA, American Society for Anesthesiologists; RBC, red blood cell.
[a]Bolded values indicate statistical significance.

complications. Patients experienced an increased risk of any complication (ASA class III: odds ratio [OR] = 1.89, confidence interval [CI] = 1.19-3.01, $P = .0070$; ASA class IV: OR = 3.58, CI = 2.00-6.39; *c*-statistic = 0.7973), LOS ≥5 days (ASA class IV: OR = 3.34, CI = 1.91-5.84; *c*-statistic = 0.7706), pulmonary complication (ASA class IV: OR = 8.81, CI = 1.14-68.33, $P = .0373$; *c*-statistic = 0.7733), intra-/postoperative RBC transfusion (ASA class III: OR = 1.69, CI = 1.04-2.76, $P = .0349$; ASA class IV: OR = 2.52, CI = 1.37-4.62, $P = .0029$; *c*-statistic = 0.8104), and reoperation (ASA class IV: OR = 11.03, CI = 1.42-85.61, $P = .0217$; *c*-statistic = 0.6544). *P* values are <.0001 unless otherwise stated.

Discussion

This study explored the role of patient ASA class assignment in improving risk stratification for patients undergoing elective ASD surgery. Higher ASA class assignment was found to be significantly and independently associated with the many acute postoperative outcomes such as any complication, LOS ≥5 days, pulmonary complications, intra-/postoperative RBC transfusion, and reoperation (related to initial procedure).

The bivariate analysis (Table 2) in this study was most useful in illustrating the differences in characteristics of patients between the low and high ASA class cohorts. In patient

Table 3. Unadjusted Outcomes (N = 5803).[a]

	ASA Class I		ASA Class II		ASA Class III		ASA Class IV		
Category	n	%	n	%	n	%	n	%	*P* Value
Mortality	0	0.0%	1	0.0%	23	0.8%	6	3.8%	**<.0001**
Any complication	27	17.4%	635	24.8%	1076	36.8%	83	51.9%	**<.0001**
LOS ≥5 days	32	20.6%	542	21.2%	1013	34.6%	88	55.0%	**<.0001**
Wound complication	1	0.6%	40	1.6%	94	3.2%	7	4.4%	**.0005**
Pulmonary complication	1	0.6%	37	1.4%	99	3.4%	19	11.9%	**<.0001**
Venous thromboembolism	2	1.3%	43	1.7%	53	1.8%	7	4.4%	.1682
Renal complication	1	0.6%	16	0.6%	40	1.4%	1	0.6%	.0891
Urinary tract infection	1	0.6%	37	1.4%	80	2.7%	5	3.1%	**.0095**
Peripheral nerve injury	0	0.0%	0	0.0%	5	0.2%	1	0.6%	.0806
Cardiac complication	0	0.0%	6	0.2%	26	0.9%	7	4.4%	**<.0001**
Intra-/postoperative RBC transfusion	24	15.5%	557	21.7%	928	31.7%	66	41.3%	**<.0001**
Sepsis	0	0.0%	23	0.9%	69	2.4%	10	6.3%	**<.0001**
CNS complication	0	0.0%	5	0.2%	6	0.2%	1	0.6%	.7909
Reoperation (related to initial procedure)	1	0.7%	69	2.9%	134	4.9%	14	9.6%	**<.0001**
Unplanned readmission (related to initial procedure)	5	3.5%	98	4.2%	211	7.8%	18	12.3%	**<.0001**

Abbreviations: ASA, American Society for Anesthesiologists; LOS, length of stay; RBC, red blood cell; CNS, central nervous system.
[a]Bolded values indicate statistical significance.

demographics, old age had a significant correlation with higher ASA. Although ASA class assignment is not dependent on this variable, it may instead function as a confounder. Stratification by age revealed that the incidence of pulmonary and cardiac comorbidities, two leading drivers of higher ASA class assignment, increased with older age in this study's patient population. This may explain the difference seen in age between these ASA class cohorts.

Bivariate analysis also revealed that patients with a higher comorbidity burden was correlated with higher ASA scores. Since ASA class is dependent on physical status, which is dependent on patient preoperative health, this observed result agrees with ASA class assignment guidelines, as well as other previous literature in spinal surgeries.[6-13] Interestingly, the prevalence of smoking in the higher ASA class cohort was not significantly different than that of the lower ASA class. ASA guidelines register current smokers automatically into ASA class II, but there is no concrete information on how the degree of smoking, aside from conferred illnesses that more relate to a patient's current disease states, plays a role in ASA class assignment. Because NSQIP registers patient smoking as binary and fails to capture the degree of smoking, these 2 factors may have led to this result.

Most important, on multivariate analysis, increasing ASA class was identified as an independent risk factor for many postoperative complications. Pateder et al echoed these results in their study, which identified the bivariate association between ASA class and mortality.[17] Smith et al conducted a prospective, multicenter, 2-year follow-up of patients following ASD surgery and found that higher, perioperative (<6 weeks from operation) complication rates (ie, overall morbidity) are associated with patients who have greater preoperative comorbidities.[18] Mannion et al used the Eurospine Spine Tango Registry to create a cohort of patients undergoing spine surgery for degenerative lumbar disorders and found ASA class to be an independent risk factor of surgical and general complication incidence in patients undergoing any spine surgery.[19] Preoperative patient comorbidities have been shown to increase complication rates in spinal surgery.[18,19] Similarly, ASA class is an effective surrogate for patient preoperative comorbidities, and therefore, advanced ASA class acts as a risk factor for postoperative adverse events. This is in line with other studies that have shown ASA class to correlate with and increased incidence of postoperative complications following spine surgery.[6,7,9,12,20]

All of the postoperative adverse events where ASA class was identified as a risk factor generally had modest *c*-statistic values (Table 6). For example, in other spinal surgeries, ASA class has been implicated as a risk factor for wound complications.[10,13] This may be justified by the fact that ASA class encapsulates diabetes and obesity, both of which have been associated with a greater risk of surgical site infections as a result of tissue hypoperfusion and subsequently impaired immunological function.[21] Finally, ASA class is a proxy for patients' preoperative health and encapsulates multiple comorbidities that are known to be risk factors for cardiac complications,[22] pulmonary complications,[23] postoperative sepsis,[22,24] UTI,[24] and intra-/postoperative transfusion.[25] A greater incidence of these complications can lead to prolonged length of hospital stay.

The key findings from this study were different than the conclusions from Schwab et al,[14] which may have stemmed from differences in study design. Schwab et al divided their patient population into a complication cohort and control cohort. The complication cohort was collected by a nonrandom, retrospective consecutive sampling method, and the control cohort was randomly selected from a time-matched sample. The advantage of using this method, as Schwab et al did, is that the optimization algorithm for multivariate logistic regression will be less likely to generate a model with low

Table 4. Subgroup Bivariate Analysis Between ASA II and ASA III Patients for Patient Characteristics (N = 5488).[a]

	ASA Class II		ASA Class III		
Category	n	%	n	%	*P*
Sex					
Female	1547	60.4%	1719	58.7%	.2067
Male	1014	39.6%	1208	41.3%	
Age ≥65 years	782	30.5%	1423	48.6%	**<.0001**
Race					
White	2093	81.7%	2374	81.1%	.1546
Other	201	7.8%	203	6.9%	
Hispanic	93	3.6%	110	3.8%	
Black	174	6.8%	240	8.2%	
Obese	919	35.9%	1421	48.5%	**<.0001**
Diabetes	161	6.3%	627	21.4%	**<.0001**
Dyspnea	86	3.4%	233	8.0%	**<.0001**
Partially or totally dependent functional status	60	2.3%	177	6.0%	**<.0001**
Pulmonary comorbidity	53	2.1%	211	7.2%	**<.0001**
Cardiac comorbidity	1081	42.2%	1956	66.8%	**<.0001**
Renal comorbidity	2	0.1%	14	0.5%	**.0061**
Smoke	523	20.4%	621	21.2%	.4697
Steroid use	48	1.9%	146	5.0%	**<.0001**
Recent weight loss	0	0.0%	10	0.3%	**.0031**
Bleeding disorder	14	0.5%	48	1.6%	**.0001**
Preoperative RBC transfusion	3	0.1%	10	0.3%	.0879
Operation time ≥4 hours	1092	42.6%	1534	52.4%	**<.0001**
Operation year					
2010	220	8.6%	221	7.6%	.2526
2011	146	5.7%	185	6.3%	
2012	178	7.0%	218	7.4%	
2013	957	37.4%	1041	35.6%	
2014	1060	41.4%	1262	43.1%	
Osteotomy	325	12.7%	474	16.2%	**.0002**
Fusion to pelvis	165	6.4%	305	10.4%	**<.0001**
Fusion length					
Long	1522	59.4%	1931	66.0%	**<.0001**
Short	1039	40.6%	996	34.0%	
Surgical approach					
Posterior	1272	49.7%	1827	62.4%	**<.0001**
Anterior	1177	46.0%	1009	34.5%	
Combined	112	4.4%	91	3.1%	

Abbreviations: ASA, American Society for Anesthesiologists; RBC, red blood cell.
[a]Bolded values indicate statistical significance.

sensitivity and specificity (ie, low *c*-statistic). However, this study ensures that this advantage is mirrored by taking into account *c*-indices when looking at multivariate regression model accuracies. The differences between this study and Schwab's, then, stem from the different sampling procedures used. Given that nonrandom sampling has a greater risk of creating a sample that may not be the best representation of the true population,[26] NSQIP, given its much larger data size, is more likely to represent this true ASD population, helping bolster the reliability of outcomes in this study.

However, there are several limitations that must be addressed in this work. Because the NSQIP database classifies cases based on CPT codes, differences between procedural techniques cannot be accounted for in this study. The NSQIP database does not delineate patients by ICD-9 codes, which presents an inherent limitation of the database. We attempted to control for variables that we considered surrogates for case complexity such as operative duration, presence or absence of an osteotomy, pelvic fixation, surgical approach, long fusion lengths, and total relative value units in our multivariate regression analysis. Furthermore, NSQIP offers a large patient size but may overrepresent academic US medical centers. Additionally, long-term complications, radiological outcomes, and other spine-specific variables are not captured in the NSQIP database, which only evaluates complications up to 30 days postoperatively, leading to a potential underestimation of risk. Finally, interrater reliability of ASA class are not perfect, even though ASA class assignment has been known to achieve 98% reliability (±1 class) across different anesthesiologists.[27]

Table 5. Subgroup Bivariate Analysis Between ASA II and ASA III Patients for 30-Day Outcomes (N = 5488).[a]

Category	ASA Class II		ASA Class III		*P* Value
	n	%	n	%	
Mortality	1	0.0%	23	0.8%	**<.0001**
Any complication	635	24.8%	1076	36.8%	**<.0001**
LOS ≥5 days	542	21.2%	1013	34.6%	**<.0001**
Wound complication	40	1.6%	94	3.2%	**.0001**
Pulmonary complication	37	1.4%	99	3.4%	**<.0001**
Venous thromboembolism	43	1.7%	53	1.8%	.7104
Renal complication	16	0.6%	40	1.4%	**.0064**
Urinary tract infection	37	1.4%	80	2.7%	**.0010**
Peripheral nerve injury	0	0.0%	5	0.2%	**.0364**
Cardiac complication	6	0.2%	26	0.9%	**.0015**
Intra-/postoperative RBC transfusion	557	21.7%	928	31.7%	**<.0001**
Sepsis	23	0.9%	69	2.4%	**<.0001**
CNS complication	5	0.2%	6	0.2%	.9358
Reoperation (related to initial procedure)	69	2.9%	134	4.9%	**.0003**
Unplanned readmission (related to initial procedure)	98	4.2%	211	7.8%	**<.0001**

Abbreviations: ASA, American Society for Anesthesiologists; LOS, length of stay; RBC, red blood cell; CNS, central nervous system.
[a]Bolded values indicate statistical significance.

Table 6. Multivariate Logistic Regression Results for ASA Class as a Risk Factor for Adverse Outcomes Following Elective ASD Surgery.[a]

Outcome	ASA Class	Odds Ratio	Lower Confidence Limit	Upper Confidence Limit	*P* Value	*c*-statistic
Any complication	ASA class II vs ASA class I	1.36	0.86	2.16	.1934	0.7973
	ASA class III vs ASA class I	1.89	1.19	3.01	**.0070**	
	ASA class IV vs ASA class I	3.58	2.00	6.39	**<.0001**	
LOS ≥5 days	ASA class II vs ASA class I	0.93	0.60	1.45	.7622	0.7706
	ASA class III vs ASA class I	1.54	0.99	2.38	.0545	
	ASA class IV vs ASA class I	3.34	1.91	5.84	**<.0001**	
Pulmonary complication	ASA class II vs ASA class I	1.78	0.24	13.11	.5733	0.7733
	ASA class III vs ASA class I	3.18	0.44	23.23	.2536	
	ASA class IV vs ASA class I	8.81	1.14	68.33	**.0373**	
Intra-/postoperative RBC transfusion	ASA class II vs ASA class I	1.32	0.81	2.15	.2726	0.8104
	ASA class III vs ASA class I	1.69	1.04	2.76	**.0349**	
	ASA class IV vs ASA class I	2.52	1.37	4.62	**.0029**	
Reoperation (related to initial procedure)	ASA class II vs ASA class I	3.97	0.55	28.83	.1726	0.6544
	ASA class III vs ASA class I	5.91	0.82	42.66	.0784	
	ASA class IV vs ASA class I	11.03	1.42	85.61	**.0217**	

Abbreviations: ASA, American Society for Anesthesiologists; LOS, length of stay; RBC, red blood cell.
[a]Bolded values indicate statistical significance.

Despite these limitations, this is the first study evaluating the role of ASA class in ASD surgery with a large patient database. ASA class can intuitively be appreciated as a tool in patient risk stratification since it inherently captures a large spectrum of patient comorbidities. In this study, this notion was verified, with higher ASA class assignments showing significant and independent correlation with any complications, LOS ≥5 days, pulmonary complications, intra-/postoperative RBC transfusions, and reoperation. These results suggest the utility of ASA class in refining the risk stratification profile and improving preoperative patient counseling for those individuals undergoing ASD surgery.

Authors' Note

This study was qualified as exempt by the Mount Sinai Hospital Institutional Review Board. This study was previously presented as a "Podium Presentation" at the Lumbar Spine Research Society 2016 Annual Meeting on April 14, 2016, in Chicago, Illinois.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr Cho reports personal fees from Stryker and nonfinancial support from Zimmer, outside the submitted work. The remaining authors have no conflicts of interest to disclose.

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