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Predicting 30-Day Perioperative Outcomes in Adult Spinal Deformity Patients With Baseline Paralysis or Functional Dependence

HADDY ALAS, BS[1]; RIVKA C. IHEJIRIKA, MD[1]; NICHOLAS KUMMER, BS[1]; LARA PASSFALL, BS[1]; OSCAR KROL, BA[1]; COLE BORTZ, BA[1]; KATHERINE E. PIERCE, BS[1]; AVERY BROWN, BS[1]; DENNIS VASQUEZ-MONTES, MS[1]; BASSEL G. DIEBO, MD[2]; CARL B. PAULINO, MD[2]; RAFAEL DE LA GARZA RAMOS, MD[3]; MUHAMMAD B. JANJUA, MD[4]; MICHAEL C. GERLING, MD[1]; AND PETER G. PASSIAS, MD[1]

[1]*Division of Spinal Surgery/Departments of Orthopaedic and Neurosurgery, NYU Langone Medical Center, NY Spine Institute, New York, NY, USA;* [2]*Department of Orthopedic Surgery, SUNY Downstate, New York, NY, USA;* [3]*Department of Neurosurgery, Bronx-Lebanon Hospital Center, New York, NY, USA;* [4]*Department of Pediatric Neurosurgery, UT Southwestern Medical Center, Dallas, TX, USA*

ABSTRACT

Background: Patients undergoing surgical treatment of adult spinal deformity (ASD) are often preoperatively risk stratified using standardized instruments to assess for perioperative complications. Many ASD instruments account for medical comorbidity and radiographic parameters, but few consider a patient's ability to independently accomplish necessary activities of daily living (ADLs).

Methods: Patients ≥18 years undergoing ASD corrective surgery were identified in National Surgical Quality Improvement Program. Patients were grouped by (1) plegic status and (2) dependence in completing ADLs ("totally dependent" = requires total assistance in ADLs, "partially dependent" = uses prosthetics/devices but still requires help, "independent" = requires no help). Quadriplegics and totally dependent patients comprised "severe functional dependence," paraplegics/hemiplegics who are "partially dependent" comprised "moderate functional dependence," and "independent" nonplegics comprised "independent." Analysis of variance with post hoc testing and Kruskal-Wallis tests compared demographics and perioperative outcomes across groups. Logistic regression found predictors of inferior outcomes, controlling for age, sex, body mass index (BMI), and invasiveness. Subanalysis correlated functional dependence with other established metrics such as the modified Frailty Index (mFI) and Charlson Comorbidity Index (CCI).

Results: A total of 40,990 ASD patients (mean age 57.1 years, 53% women, mean BMI 29.8 kg/m^2) were included. Mean invasiveness score was 6.9 ± 4.0; 95.2% were independent (Indep), 4.3% moderate (Mod), and 0.5% severe (Sev). Sev had higher baseline invasiveness than Mod or Indep groups (9.0, 8.3, and 6.8, respectively, $P < 0.001$). Compared with the Indep patients, Sev and Mod had significantly longer inpatient length of stay (LOS; 10.9, 8.4, 3.8 days, $P < 0.001$), higher rates of surgical site infection (2.2%, 2.9%, 1.5%, $P < 0.001$), and more never events (17.7%, 9.9%, 4.0%, $P < 0.001$). Mod had higher readmission rates than either the Sev or Indep groups (30.2%, 2.7%, 10.3%, $P < 0.001$). No differences in implant failure were observed ($P > 0.05$). Controlling for age, sex, BMI, CCI, invasiveness, and frailty, regression equations showed increasing functional dependence significantly increased odds of never events (OR, 1.82 [95% CI 1.57–2.10], $P < 0.001$), specifically urinary tract infection (OR, 2.03 [95% CI 1.66–2.50], $P < 0.001$) and deep venous thrombosis (OR, 2.04 [95% CI 1.61–2.57], $P < 0.001$). Increasing functional dependence also predicted longer LOS (OR, 3.16 [95% CI 2.85–3.46], $P < 0.001$) and readmission (OR, 2.73 [95% CI 2.47–3.02], $P < 0.001$). Subanalysis showed functional dependence correlated more strongly with mFI ($r = 0.270$, $P < 0.001$) than modified CCI (mCCI; $r = 0.108$, $P < 0.001$), while mFI and mCCI correlated most with one another ($r = 0.346$, $P < 0.001$).

Conclusions: Severe functional dependence had significantly longer LOS and more never-event complications than moderate or independent groups. Overall, functional dependence may show superiority to traditional metrics in predicting poor perioperative outcomes, such as increased LOS, readmission rate, and risk of surgical site infection and never events.

Level of Evidence: 3.

Complications

Keywords: adult spinal deformity, functional dependence, paralysis, length of stay, hospital-acquired conditions, never events

INTRODUCTION

Adult spinal deformity (ASD) predominantly results from degenerative changes to the vertebral discs, facet joints, and bodies over time due to osteoporosis and muscle atrophy. Progressive deformity can occur in both the sagittal and coronal planes and is estimated to affect over 65% of adults older than 60 years.[1] In symptomatic cases, patients typically present with low back pain, neurogenic claudication, radicular leg pain,

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and weakness. Several parameters including pelvic tilt, pelvic incidence, lumbar lordosis, and sagittal vertical axis are used to classify the deformity and guide surgical intervention. Patients' health-related quality of life (HRQOL) has been tied to these measurements (sagittal vertical axis >47 mm, pelvic tilt >22°, pelvic incidence minus lumbar lordosis >11°) and a patient-reported Oswestry Disability Index (ODI) score above 40.[2,3] While literature suggests disabled patients with these parameters are more likely to have a clinically important improvement after undergoing ASD surgery, a subset of these patients may be at higher risk for complications and are not accounted for in standard assessments.[3–5]

As health care reimbursement models have been changing based on outcomes and readmission rates, there has been an increased emphasis on patient selection and preoperative optimization prior to ASD surgery. Traditional risk factors associated with poor outcomes after ASD surgery have been age, procedural length or complexity, and medical comorbidities, such as obesity, cardiac, pulmonary, or renal disease.[6–8] These factors in isolation are insufficient to risk stratify patients with regards to outcomes.

Comprehensive tools such as an assessment of frailty and function rather than patient self-assessments and radiographs alone should supplement the operative decision-making process.[9–11] Frailty, or an increased vulnerability to injury, reflects a patient's physiologic age and is heavily impacted by their level of functional independence. It is associated with higher rates of proximal junctional kyphosis, infection, wound dehiscence, length of stay (LOS), blood loss, morbidity, and mortality.[4,12,13] Despite this, preoperative functional dependence remains of secondary importance with regard to operative planning.

The goal of this study was to assess the utility of functional dependence and paralysis as predictors for perioperative complications in a population of patients undergoing ASD surgery. We hypothesized that patients' poor preoperative functional status or increasing dependence on aides for ADLs would have worse outcomes after ASD surgery compared with those who were independent.

MATERIALS AND METHODS

Data Source

The American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) database was used to analyze adults undergoing surgical correction for ASD. Developed by the US Department of Veterans Affairs, the ACS-NSQIP tracks the outcomes of risk-adjusted surgical interventions via patient data reports from hospitals across the United States. Trained surgical clinical reviewers collect data from randomly assigned patients through medical chart review, letters, or phone calls, ensuring standardization and reliability within the database. The ACS-NSQIP tracks 135 clinical metrics including preoperative risk factors, intraoperative variables, 30-day postoperative outcomes, current procedural terminology (CPT) coding, and International Classification of Disease Ninth Edition (ICD-9) codes, with a 95% successful capture rate in 30-day outcomes. Patients younger than 18 years, trauma cases, and cases with CPT codes not on the CPT code inclusion list were excluded from the database. In addition, hospitals with a 30-day follow-up rate lower than 80% or inter-rater reliability audit disagreement rate over 5% were excluded. More information on ACS-NSQIP is available at https://www.facs.org/quality-programs/acs-nsqip/about.

Study Design

The present study is a retrospective review of the ACS-NSQIP database from 2005 to 2015. Inclusion criteria were patients older than 18 years undergoing thoracolumbar spine fusion or decompression. An elective surgical ASD population was isolated using appropriate CPT codes as previously published.[14] Patients with pneumonia, sepsis, tumor of the central nervous system, disseminated cancer, a prior operation within the past 30 days, or an emergency trauma were excluded. The CPT and International Classification of Disease Ninth Edition codes can be found listed in Appendix A. "Never events" comprise instances of urinary tract infection, surgical site infection (SSI), pulmonary embolism, and deep vein thrombosis.[15]

Statistical Methods

Patients who met initial surgical ASD criteria were grouped by "functional dependence" as defined by the following variables: (1) plegic/paralysis status and (2) dependence in activities of daily living (ADLs). Plegic status was stratified into aplegia, hemiplegia, paraplegia, and quadriplegia. Hemiplegia was defined as total or partial paralysis or paresis of one side of the body, paraplegia was defined as total or partial paralysis or paresis of the lower extremities, and quadriplegia was total or partial paralysis or paresis of all 4 extremities. Dependence in ADLs was stratified into totally dependent, partially dependent, and independent. Totally

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dependent was defined as a patient requiring total assistance in completing ADLs, partially dependent was defined as a patient who requires some assistance from another person for ADLs, including use of prosthetics, equipment, or devices, and independent was defined as a patient who requires no help in ADLs. Incremental categories of "functional dependence" were then established: quadriplegic patients or those totally dependent in ADLs comprised the severe functional dependence group; paraplegics, hemiplegics, or those partially dependent in ADLs comprised the moderate functional dependence group; and aplegics or those independent in ADLs comprised the functional independence group.[16,17]

Demographics and 30-day perioperative outcomes including total inpatient LOS, readmission, hospital-acquired conditions or "never events," implant failure, and discharge deposition were compared across severe, moderate, and independent functional groups using analysis of variance for continuous variables and Kruskal-Wallis tests with post hoc Mann-Whitney *U* tests for categorical or ordinal variables. Predictors of inferior outcomes were investigated using multivariate logistic regression equations with 95% CIs, each controlling for patient age, sex, body mass index (BMI), and surgical invasiveness. A subanalysis with Pearson's *r* was performed to correlate functional dependence with other established metrics, including the Charlson Comorbidity Index (CCI) and modified Frailty Index (mFI), which are commonly used in preoperative stratification of the surgical ASD population. A *P* value less than 0.05 was considered statistically significant. All statistic analyses were performed using SPSS software version 23.0 (Armonk, NY, USA).

RESULTS

Overall ASD Cohort Characteristics

This analysis included 40,990 thoracolumbar ASD patients (mean age: 57.1 ± 15 years, 53% women, BMI 29.8 ± 7.0 kg/m^2) undergoing surgical correction between 2005 and 2015. Overall cohort surgical characteristics were 1.9 ± 2.4 levels fused, with 50.0% undergoing an anterior approach, 40.5% undergoing a posterior approach, and 8.9% undergoing a combined approach; 26.9% underwent posterior decompression and 15.3% underwent anterior decompression, with 25.2% undergoing laminectomy and 7.3% undergoing laminotomy. Of the 3.8% of patients who underwent osteotomy, 82.1% underwent Smith-Peterson osteotomy and 17.9% underwent 3-column osteotomy.

Differences Across Functional Dependence Groups

Within our cohort (*N* = 40,990), the majority met definitions for functional independence (95.2%), followed by moderate functional dependence (4.3%), and severe functional dependence (0.5%). Groups differed in baseline age, BMI, sex, invasiveness index, and CCI

Table. Demographics, complications, outcomes, and discharge disposition across functional dependence groups. Increasing functional dependence category was analyzed as a predictor for various inferior outcomes with 95% CIs.

	Functional Dependence Groups				Increasing Functional Dependence		
Characteristics	**Independent (*N* = 39,030)**	**Moderate (*N* = 1774)**	**Severe (*N* = 186)**	***P* Value**	**OR**	**95% CI**	***P* Value**
Demographics							
Age (y)	57 ± 13	62 ± 14	56 ± 19	<0.001[a]	3.41	(2.89–3.95)	<0.001[a]
Body mass index (kg/m^2)	30 ± 6.5	30 ± 7.8	28 ± 9.5	0.005[a]	−0.24	(−0.50 to 0.03)	0.084
Sex (% women)	53%	49%	49%	0.002[a]	0.87	(0.80–0.95)	0.001[a]
Invasiveness index	6.8 ± 3.9	8.3 ± 4.9	9.0 ± 6.1	<0.001[a]	1.37	(1.21–1.53)	<0.001[a]
Charlson Comorbidity Index	2.4 ± 1.6	3.4 ± 2.1	3.0 ± 2.3	<0.001[a]	0.73	(0.66–0.80)	<0.001[a]
Complications							
Surgical site infection	1.5%	2.9%	2.2%	<0.001[a]	1.48	(1.15–1.90)	0.002[a]
Urinary tract infection	1.5%	4.5%	11.3%	<0.001[a]	2.45	(2.04–2.95)	<0.001[a]
Deep venous thrombosis	1.2%	3.7%	5.4%	<0.001[a]	2.12	(1.71–2.63)	<0.001[a]
Implant failure	2.2%	2.8%	2.2%	0.140	1.06	(0.82–1.36)	0.668
Clinical outcomes							
Inpatient length of stay (d)	3.8 ± 7.6	8.4 ± 9.4	10.9 ± 13	<0.001[a]	3.38	(3.08–3.68)	<0.001[a]
Any readmission	10.3%	30.2%	2.7%	<0.001[a]	2.72	(2.48–2.98)	<0.001[a]
Never events overall	4.0%	9.9%	17.7%	<0.001[a]	1.97	(1.72–2.26)	<0.001[a]
Discharge disposition							
Home	77.1%	32.6%	26.9%	<0.001[a]	0.21	(0.19–0.23)	<0.001[a]
Subacute rehab	7.5%	19.7%	16.7%	<0.001[a]	1.63	(1.63–1.45)	<0.001[a]
Acute care facility	0.3%	1.5%	3.2%	<0.001[a]	2.69	(1.87–3.86)	<0.001[a]
Skilled nursing facility	7.1%	17.5%	18.8%	<0.001[a]	1.51	(1.33–1.71)	<0.001[a]
Expired	0.2%	0.9%	3.8%	<0.001[a]	2.54	(1.67–3.84)	<0.001[a]

[a]Statistically significant at $P < 0.05$.

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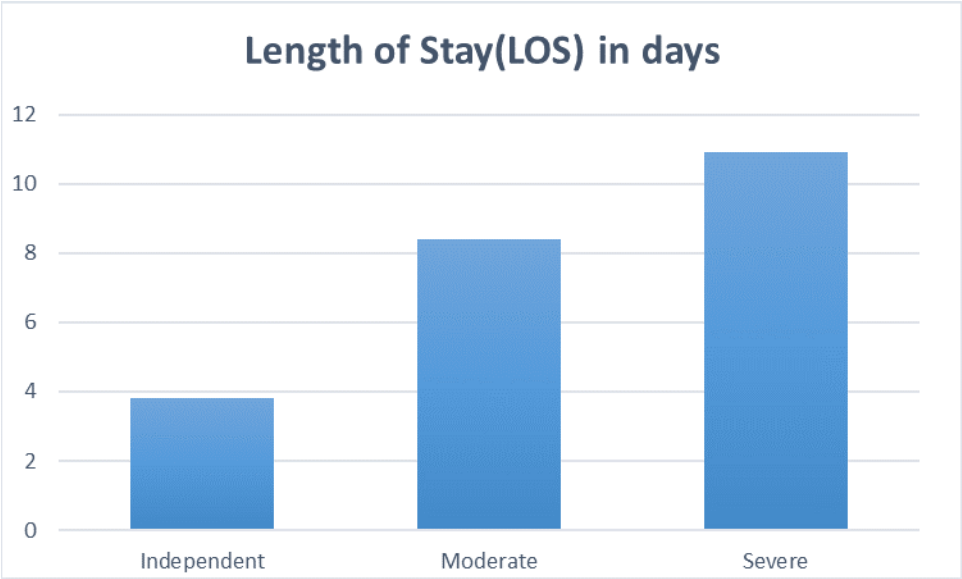

Figure 1. Length of stay in days across functional dependence groups.

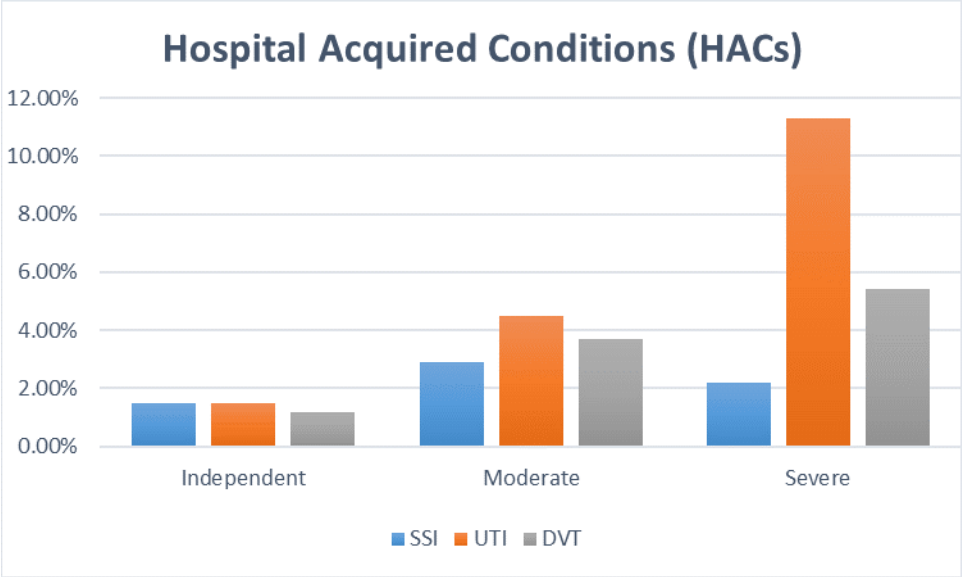

Figure 2. Three of the most common hospital-acquired conditions or "never events" associated with spine surgery patients, stratified across functional dependence groups. Patients with severe functional dependence had the highest rates of urinary tract infection (UTI) and deep venous thrombosis (DVT), whereas patients with moderate functional dependence had the highest rates of surgical site infection (SSI).

(all $P < 0.05$, Table), with moderate being older on average (62 ± 14 years) with higher BMI (30 ± 7.8) and CCI (3.4 ± 2.1) compared with other groups.

Compared with independent (3.8 days), moderate (8.4 days), and severe (10.9 days) functional dependence groups had significantly longer average inpatient LOS ($P < 0.001$, Figure 1). Moderate functional dependence patients had the highest rates of SSI at 2.9%, followed by severe (2.2%), and independent (1.5%) ($P < 0.001$). Severe functional dependence groups had the highest rates of urinary tract infection (UTI) and deep venous thrombosis (DVT) at 11.3% and 5.4%, respectively, and also carried the highest overall never-event rate (17.7% vs 9.9% vs 4.0%, $P < 0.001$, Figure 2).

Moderate functional dependence patients had the highest rate of readmission within 30 days (30.2%) compared with severe (2.7%) or independent (10.3%) groups ($P < 0.001$, Figure 3). There was no significant difference, however, in rates of implant failure across groups (2.2% vs 2.8% vs 2.2%, $P = 0.140$).

Discharge disposition differed across groups, with the majority of functionally independent

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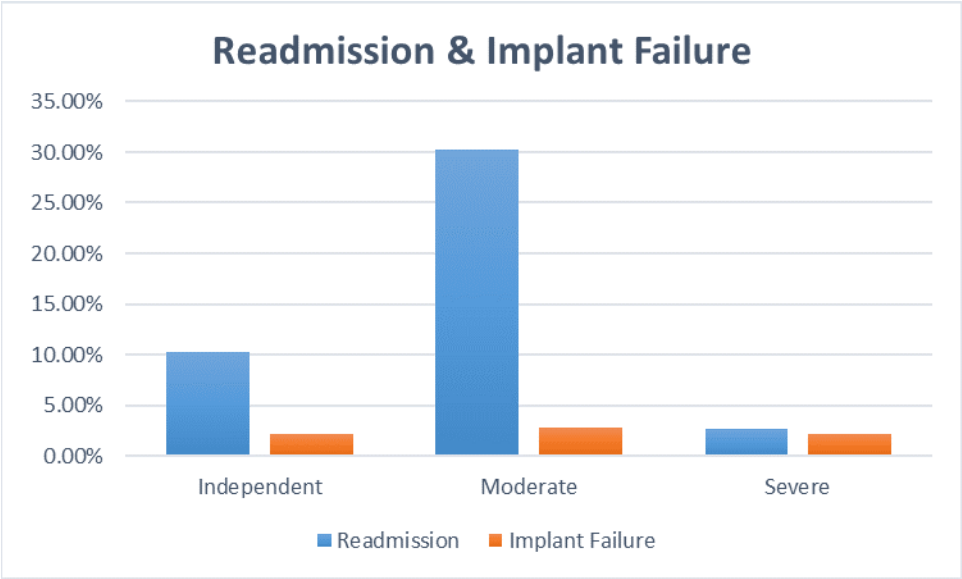

Figure 3. Readmission and implant failure rates across functional dependence groups. Moderate functional dependence patients had the highest rates of readmission; however rates of implant failure did not differ significantly between groups ($P > 0.05$).

patients being discharged home (77.1%) as opposed to 32.6% in the moderate group and 26.9% in the severe group ($P < 0.001$). In addition, differences in rates of discharge to subacute rehab, acute care facilities, and skilled nursing facilities were found between independent and moderate/severe groups (all $P < 0.001$). Within moderate and severe functional dependence groups only, however, no statistically significant differences were found in discharge disposition to any location, though severe patients trended higher rates of discharge to acute care facilities (3.2% vs 1.5%, $P = 0.072$). Severe functional dependence patients showed significantly higher rates of expiration within 30 days compared with moderate (0.9%, $P < 0.001$) or independent (0.2%, $P < 0.001$) groups.

Functional Dependence as a Predictor of Inferior 30-Day Outcomes

Controlling for baseline age, sex, BMI, CCI, invasiveness, and frailty, logistic regression sampling showed increasing functional dependence category significantly increased odds of hospital-acquired conditions or never events (OR, 1.82 [95% CI 1.57–2.10], $P < 0.001$), specifically UTI (OR, 2.03 [95% CI 1.66–2.50], $P < 0.001$) and DVT (OR, 2.04 [95% CI 1.61–2.57], $P < 0.001$).

Increasing functional dependence was also identified as a significant predictor of greater total hospital LOS (OR, 3.16 [95% CI 2.85–3.46], $P < 0.001$) and readmission within 30 days (OR, 2.73 [95% CI 2.47–3.02], $P < 0.001$). Increasing functional dependence was not, however, predictive of implant failure after ASD surgery (OR, 1.06 [95% CI 0.82–1.36], $P = 0.668$).

In terms of discharge disposition, increasing functional dependence most strongly predicted discharge to an acute care facility, increasing odds by 2.69. Increasing functional dependence increased odds of expiration within 30 days by a factor of 2.54 and predicted lower odds of discharge to home after surgery (OR, 0.21 [95% CI 0.19–0.24], $P < 0.001$) (Table).

Subanalysis Correlating Functional Dependence With Clinical Instruments

Subanalysis showed functional dependence, as defined by plegic status and ADLs, correlated more strongly with the mFI ($r = 0.270$, $P < 0.001$) than the modified CCI ($r = 0.108$, $P < 0.001$), while the mFI and modified CCI correlated most strongly with one another ($r = 0.346$, $P < 0.001$).

DISCUSSION

As ASD surgery is time-consuming, expensive, and often fraught with complications in even healthy patients, optimizing patient selection is essential. Our goal was to investigate whether preoperative functional dependence, defined through neuromuscular paralysis and ADLs, was related to complications after ASD surgery. Patients with moderate to severe functional

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dependence including partial or total dependence for ADLs, paraplegia, hemiplegia, or quadriplegia were at an increased risk for SSI, DVT, UTI, prolonged LOS, and readmission. Given the high rate of incontinence and catheterization among patients who are severely functional dependent, we note that this may be confounded by chronic colonization and this rate may not be fully representative of actual UTI. Additionally, there may have been a reduced readmission rate among patients who were severely functional dependent considering these patients historically have longer hospital stays and reduced rates of at-home discharge. Increased functional dependence is also correlated to frailty with moderate and severely dependent patients more likely to be rated as frail on the mFI scale. These findings suggest that surgeons must look beyond traditional risk stratification modalities during preoperative planning and include preoperative functional dependence in their assessment.

It has been suggested that ASD patients with the aforementioned pelvic parameters and an ODI score above 40 may benefit from surgical treatment.[2,3] While patients with severe disability may have spinopelvic parameters that warrant correction, the degree of the disability itself may be an indication to pursue nonoperative management or minimally invasive treatment. In a study by Reid et al, ASD surgery patients were categorized as being nonfrail, frail, or severely frail based on the ASD-FI.[12] They found that after undergoing multilevel ASD fusion (≥4 levels), improvements in HRQOL outcomes including the ODI, 36-item Short Form Health Survey, and 36-item Short Form Health Survey physical component score were greatest for frail and nonfrail patients. Severely frail patients had the lowest clinically important HRQOL benefits after surgery. These severely frail patients had an average preoperative ODI of 69.5 and a higher CCI than the frail and nonfrail groups. This suggests that there might be a tipping point where postoperative benefits begin to diminish based on patients declining preoperative functional ability.

While Reid et al's data suggest that not all frail patients have equivalent outcomes, it is important to reconcile this with evidence that functionally dependent patients are more likely to have postoperative complications. As the ASD-FI merges components of the mFI with ASD-specific indices of functional dependence and psychosocial health, it may prove worthwhile to stratify patients on a more nuanced level with these factors in mind.

The importance of functional dependence on outcomes extends beyond thoracolumbar ASD to the cervical spine and total joint arthroplasty.[18] Patients with reduced independence are more likely to undergo unplanned postoperative intubation and complications after elective cervical spine surgery, and this is exacerbated in patients with myelopathy.[19–21] Patients with reduced functional independence are also 3 times more likely to have early complications after undergoing revision spine surgery.[10]

As bundled and capitated reimbursement models are created, it is crucial for insurers to account for added patient complexity based on preoperative functional dependence in addition to medical comorbidities and frailty. Functionally dependent patients are up to 4 times more likely to be discharged to an inpatient facility rather than home after spine surgery.[22–24] Nonhome discharge itself poses a risk to patients and is associated with increased costs and complications. The average hospital LOS for ASD surgery patients who are discharged to an inpatient facility is greater than 5 days and is estimated to cost ~$1000 per day nationally. Preoperative identification of patients likely to require nonhome transfer and early discharge planning may reduce LOS and mitigate some of these costs.[24]

Other considerations should be given to preoperative optimization in this group of patients as well. Osteoporosis is not only caused by postmenopausal hormone changes but also by disuse atrophy. Reduced bone density is common in ASD patients and can contribute to back pain and spinal disease making patients more susceptible to vertebral compression fractures and progressive deformity over time.[25] While the US Preventive Services Task Force recommends that women over the age of 65 receive screening for osteoporosis, patients with low mobility are at an increased risk for osteoporosis regardless of gender or age .[26] We recommend a dual-energy x-ray absorptiometry scan and bone health assessment for all patients undergoing an evaluation for ASD who do not have functional independence.

Treatments such as teriparatide, a recombinant form of parathyroid hormone with an anabolic effect on bone metabolism, have been shown to be efficacious in increasing bone density, screw-pullout strength, and outcomes in ASD surgery.[27] Not only do drugs like teriparatide and bisphosphonates increase operative success, but studies have also shown that they may obviate the need for surgery altogether by reducing pain.[28,29] Wakao et al conducted a study looking at the effect of teriparatide on the need for spine surgery in patients with intractable back pain and paralysis. They

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found that after daily teriparatide infusion for 3 months along with physical therapy, 40% of patients with osteoporotic compression fractures, pain, and paralysis were deindicated for surgery.[29] Further research is needed to determine the impact of this medication in a controlled study.

Although taking frailty and function into account may aide with predicting outcomes after ASD surgery, treatment for some comorbid conditions may have minimal impact on improving complication rates. In a retrospective study by Yagi et al, researchers evaluated the relationship between frailty management and outcomes. They found that frail patients had similarly poor outcomes regardless of preoperative optimization of mFI illnesses such as diabetes, hypertension, chronic obstructive pulmonary disease, vascular disease, and cardiac conditions.[27]

A realistic and frank discussion regarding expected outcomes must be had with patients prior to surgery. These data combined with current literature suggest that patients who have low preoperative function will continue to have poor postoperative function after ASD corrective surgery and an increased rate of complications.[9,12] In these cases, the goals of surgery should be thoroughly evaluated. Complete pain control may not be an achievable aim for these patients although improved sitting or lying posture, horizontal gaze, and ease of transfer may be attainable.

Limitations of this study include the retrospective design and utilization of a large database to obtain data. The NSQIP database, while robust in the number of participating institutions and a breadth of information, lacks in fine detail or long-term data. Specific contributions to increased LOS in the functionally dependent patients are not available, and the low amount of patients who were severely functionally dependent may limit the applications of the results. Additionally, only 30 days of postoperative data are provided. Implant failure commonly presents on long-term follow-up. Given the relatively low osteotomy rate and low mean levels fused among the cohort, this study may also be limited by complexity of surgery in its application to clinical practice. Our finding of no difference between implant failure rates among patients with varying rates of functional independence within 30 days of surgery is not unexpected. The NSQIP database is compiled by skilled reviewers; however, there may also be errors in data collection or reporting bias.

Future directions of this work are to investigate the HRQOL outcomes comparing nonoperative and operative cohorts of ASD patients in a randomized controlled trial or through prospective means. Long-term investigation is warranted to identify the true impact of functional dependence on outcomes in ASD corrective surgery.

CONCLUSION

Our research suggests that functional dependence is an independent risk factor for complications after ASD surgery. Moderate and severely dependent patients should be identified early and given adequate mechanical and pharmacologic DVT prophylaxis, perianal hygiene, discharge planning, and close follow-up in anticipation of these complications. Providers should preoperatively risk stratify patients using comprehensive methods, such as the ASD-FI, which take into account medical comorbidities, frailty, and functional dependence. The high risk of complications in patients with severe functional deficits may outweigh the benefits they will receive from ASD surgery. Careful selection and counseling are necessary when managing these patients.

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Corresponding Author: Peter G. Passias, New York Spine Institute, New York University Medical Center - Hospital for Joint Diseases, 301 E 17th St, New York, NY 10003, USA; peter.passias@nyumc.org

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