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Indicators for Nonroutine Discharge Following Cervical Deformity-Corrective Surgery: Radiographic, Surgical, and Patient-Related Factors

BACKGROUND: Nonroutine discharge, including discharge to inpatient rehab and skilled nursing facilities, is associated with increased cost-of-care. Given the rising prevalence of cervical deformity (CD)-corrective surgery and the necessity of value-based healthcare, it is important to identify indicators for nonroutine discharge.

OBJECTIVE: To identify factors associated with nonroutine discharge after CD-corrective surgery using a statistical learning algorithm.

METHODS: A retrospective review of patients ≥ 18 yr with discharge and baseline (BL) radiographic data. Conditional inference decision trees identified factors associated with nonroutine discharge and cut-off points at which factors were significantly associated with discharge status. A conditional variable importance table used nonreplacement sampling set of 10 000 conditional inference trees to identify influential patient/surgical factors. The binary logistic regression indicated odds of nonroutine discharge for patients with influential factors at significant cut-off points.

RESULTS: Of 138 patients (61 yr, 63% female) undergoing surgery for CD (8 ± 5 levels; 49% posterior approach, 16% anterior, and 35% combined), 29% experienced nonroutine discharge. BL cervical/upper-cervical malalignment showed the strongest relationship with nonroutine discharge: C1 slope $\geq 14^\circ$, C2 slope $\geq 57^\circ$, TS-CL $\geq 57^\circ$. Patient-related factors associated with nonroutine discharge included BL gait impairment, age ≥ 59 yr and apex of CD primary driver $\geq C7$. The only surgical factor associated with nonroutine discharge was fusion ≥ 8 levels. There was no relationship between nonhome discharge and reoperation within 6 mo or 1 yr (both $P > .05$) of index procedure. Despite no differences in BL EQ-5D ($P = .946$), nonroutine discharge patients had inferior 1-yr postoperative EQ-5D scores ($P = .044$).

CONCLUSION: Severe preoperative cervical malalignment was strongly associated with nonroutine discharge following CD-corrective surgery. Age, deformity driver, and ≥ 8 level fusions were also associated with nonroutine discharge and should be taken into account to improve patient counseling and health care resource allocation.

KEY WORDS: Cervical deformity, Surgery, Discharge, CD, Rehabilitation, Skilled nursing facility, Outcomes

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Outcomes following cervical deformity (CD)-corrective surgery are a subject of increased attention in the literature, with recent reports aiming to identify treatment

strategies associated with satisfactory postoperative clinical gains.¹ Although numerous reports show favorable clinical outcomes following CD-corrective surgery, the postoperative course of

ABBREVIATIONS: BL, baseline; BMI, body mass index; CCI, Charlson Comorbidity Index; CD, cervical deformity; CI, confidence interval; CL, cervical lordosis; cSVA, cervical sagittal vertical axis; EBL, estimated blood loss; HRQL, health-related quality-of-life; ISSG, International Spine Study Group; LL, lumbar lordosis; LOS, length of stay; mJOA, Modified Japanese Orthopaedic Association questionnaire; NDI, Neck Disability Index; OR, odds ratios; PI, pelvic incidence; QOL, Quality-of-Life; TK, thoracic kyphosis

recovery may be protracted and expensive, with total surgical costs-of-care surpassing \$55 000.²⁻⁴ Given the high physical and financial burdens of CD-corrective surgery, it is important to identify surgical and patient-related factors that both contribute to satisfactory clinical outcomes and reduce the overall cost associated with CD-corrective surgery.

A key factor associated with both increased cost-of-care and increased readmission rate following spine surgery is nonroutine discharge, including delayed discharge, discharge to inpatient rehab, and discharge to skilled nursing facilities.⁵ Previous research shows a significant relationship between discharge status and increased hospital charges, with 1 study showing a \$15 000 cost difference between routine and nonroutine discharge.⁶ Discharge to subacute care and inpatient rehab also places patients at increased risk for hospital-acquired conditions like infection, further highlighting the need to limit rates of nonhome discharge.⁷ As such, identifying factors associated with nonroutine discharge is critical for reducing hospital costs and improving patient outcomes.

Indicators of nonroutine discharge have previously been investigated for patients undergoing anterior cervical discectomy and fusion, as well as patients undergoing lumbar spine surgery.^{8,9} That said, there is a paucity in the literature of studies investigating indicators for nonroutine discharge following CD-corrective surgery. As such, the goal of this study is to use a statistical learning algorithm to identify complications, surgical variables, and patient-related factors associated with nonroutine discharge following CD-corrective surgery.

METHODS

Data Source

This analysis is a retrospective review of a prospective, multicenter database of patients with surgical CD enrolled from 2013 to 2017 at 13 spine surgery centers across the United States. Patients included in the database were ≥ 18 yr and presented radiographic evidence of CD, defined by the presence of at least 1 of the following on BL imaging: cervical kyphosis (C2-7 Cobb angle $> 10^\circ$), cervical scoliosis (C2-7 coronal Cobb angle $< 10^\circ$), and C2-7 sagittal vertical axis (cSVA) > 40 mm or chin-brow vertical angle (CBVA) $> 25^\circ$. All participating centers obtained the institutional review board approval prior to patient

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enrollment, and all participating patients provided consent prior to enrollment. Additional inclusion criteria for the present analysis included available discharge status data.

Data Collection and Radiographic Assessment

Demographic and clinical data were collected from patients at the preoperative interval and included age, sex, body mass index (BMI), comorbidity status, and Charlson Comorbidity Index (CCI). Operative and complication data were collected following surgery, including operative time, estimated blood loss (EBL), surgical approach, instrumentation used, osteotomy utilization, number of levels fused, complications, reoperations, duration of stay in intensive care, hospital length of stay (LOS), and discharge status, including discharge to home, inpatient rehab, or skilled nursing facility. Health-related quality-of-life (HRQL) scores, including outcomes of the EuroQol-5D-3 L (EQ-5D), Quality-of-Life (QOL) in swallowing disorders, and Neck Disability Index (NDI) questionnaires, were collected at BL and at the 1-yr postoperative interval. Modified Japanese Orthopaedic Association questionnaire (mJOA) score was collected at BL and at the 3-mo postoperative interval to assess myelopathy severity.

Preoperative radiographs were collected from neutral cervical anterior-posterior and lateral images, and were analyzed with SpineView[®] (ENSAM, Laboratory of Biomechanics, Paris, France) software according to previously published techniques.¹⁰⁻¹² Cervical and upper-cervical radiographic parameters were assessed as previously published and included cervical lordosis (CL), cervical sagittal vertical axis (cSVA), C2-T3 CL, cSVA from C2-T3, C2 slope, C1 slope, C0 slope, T1 slope, T1 slope minus CL (TS-CL), McGregor's slope (McGS), and upper cervical curvature (C0-C2 angle).¹³

Global and spinopelvic parameters were also assessed as previously published and included lumbar lordosis (LL), thoracic kyphosis (TK), C7-S1 SVA, pelvic tilt, pelvic incidence (PI), mismatch between PI and LL (PI-LL), and C2-S1 angle.¹³

Statistical Analysis

Patients were stratified into groups by discharge type: home or nonroutine (discharge to inpatient rehab or skilled nursing facility). Overall demographic, surgical, and clinical data were first summarized with descriptive statistics, and then compared between discharge groups by using chi-squared and independent samples *t*-tests, as appropriate. Primary analysis was conducted by using the R statistical software package (version 3.2.4, R Foundation for Statistical Computing, Vienna, Austria), and it identified factors associated with nonroutine discharge. A nonreplacement sampling set of 10 000 conditional inference trees identified potential factors influential of nonroutine discharge as well as the respective importance of each variable as an indicator of nonroutine discharge. Specifically, from a pool of 267 available demographic, clinical, surgical, and radiographic variables, the top indicators of nonroutine discharge were selected according to a variable importance table, which was generated as per the conditional permutation importance defined by the "varimp" function within the R "party" package.¹⁴ An additional conditional inference tree analysis assessed significant cut-off points at which these variables were associated with nonroutine discharge status.

Secondary analysis further confirmed associations between discharge status and radiographic, patient, and surgical factors with binary logistic regression, reporting the odds ratio (OR, [95% confidence interval (CI)]) of nonroutine discharge for continuous variables and for dichotomized variables at their respective significant cut-offs. Finally, by using the

TABLE 1. Overall Demographic, Comorbidity, and Surgical Description of the Entire Patient Cohort

Demographic description	
Age (yr)	61.3 ± 10.5
Sex (% female)	63.0%
BMI (kg/m ²)	29.4 ± 7.9
CCI	0.90 ± 1.24
History of smoking	33.1%
Diabetes mellitus	8.1%
Osteoporosis	14.8%
Depression	31.9%
Surgical description	
Levels fused	8.2 ± 4.6
EBL (cc's)	845.0 ± 878.7
Operative time (min)	488.7 ± 314.4
Approach	
Anterior	15.9%
Posterior	49.3%
Combined	34.9%
Osteotomy	
Any	55.8%
Smith-Petersen	23.2%
Pedicle subtraction	14.5%
Vertebral column resection	4.3%
Decompression	56.5%

factors identified as associated with nonroutine discharge from the variable importance table as independent variables, forward stepwise multivariable linear regression was used to assess combinations of preoperative factors most strongly associated with nonroutine discharge status, controlling for fusion length and demographic variables that differed between discharge groups in univariate analysis. Descriptive analysis, secondary analysis, and all means comparison tests were performed by using SPSS software (v21.0, IBM, Armonk, New York).

RESULTS

Study Participants and Patient Characteristics

Overall, 138 surgical CD patients were included in the present analysis. Breakdown of patient discharge location was 71% home and 29% nonroutine (including 21% to inpatient rehab and 8% to skilled nursing facilities). Table 1 presents a demographic and surgical summary of the overall patient population. At BL, the overall cohort showed moderate-to-severe cervical malalignment, with a mean TS-CL of $38.0^\circ \pm 18.1^\circ$ and a mean cSVA of $46.7 \text{ mm} \pm 24.9 \text{ mm}$. Table 2 presents univariate differences between patient cohorts with respect to patient and surgical factors.

Patient-Related and Procedural Indicators of Discharge Outcome

BL patient demographics and functional status were associated with nonroutine discharge (Table 3). Specifically, in descending order of strongest association, BL physician-reported gait impairment (OR: 5.29; 95% CI: [2.25-12.42]), communication impairment as assessed by QOL in Swallowing Disorders

questionnaire communication score ≤ 52 (OR: 4.22; 95% CI: [1.55-11.50]), and age ≥ 59 yr (OR: 4.25; 95% CI: [1.63-11.05]) were all indicative of nonroutine discharge. The only procedural factor associated with nonroutine discharge status was fusion ≥ 8 levels (OR: 4.03; 95% CI: [1.78-8.56]). As continuous variables, age (Figure 1; OR: 1.08; 95% CI: [1.03-1.23]) and fusion length (OR: 1.16; 95% CI: [1.06-1.27]) were still associated with nonroutine discharge, although with lower odds than their respective dichotomized counterparts.

Radiographic Indicators of Discharge Outcome

Upper-cervical malalignment was also associated with nonroutine discharge, with C1 slope $\geq 14^\circ$ (OR: 8.35, [3.07-22.71]) and C2 slope $\geq 57^\circ$ (OR: 6.95, [1.79-8.91]) showing the strongest relationships with discharge status out of all radiographic parameters assessed (Table 3). Although the associations of cervical parameters were smaller than those of upper-cervical parameters, TS-CL $\geq 57^\circ$ (OR: 5.89, [2.19-15.85]) and cSVA $\geq 40 \text{ mm}$ (OR: 4.63, [1.97-10.87]), were still indicative of nonroutine discharge. The only noncervical radiographic parameters associated with nonroutine discharge were TK $\leq -57^\circ$ (OR: 3.85, [1.78-8.35]) and C2-S1 angle $\leq -22^\circ$ (OR: 4.75, [1.92-11.74]). Structural driver of deformity was also identified as an indicator of discharge status, as patients with primary CD drivers below C7 showed a significantly increased probability of nonroutine discharge (OR: 3.90, [1.78-8.56]). Assessed as continuous variables, all radiographic parameters described in the above analysis, including C1 slope (Figure 2), were significantly associated with nonroutine discharge, although the odds of nonroutine discharge were lower when treating these variables as continuous rather than dichotomous indicators (Table 4).

Complication Indicators of Discharge Outcome

The overall complication rate was significantly higher for nonroutine discharge patients (home: 59.2% vs nonroutine: 77.5%, $P = .041$). Development of multiple complications (OR: 4.16, [1.87-9.22]) and hospital LOS $\geq 6 \text{ d}$ were associated with nonroutine discharge (Table 3), as were EBL $\geq 900 \text{ cc}$ (OR: 3.56, [1.65-7.67]), admission to surgical intensive care unit (OR: 5.35, [1.93-14.82]), and neurologic adverse events (OR: 2.76, [1.19-6.41]). When treated as continuous variables, number of complications (Figure 3; OR: 1.5 [1.18-1.98]) and LOS (OR: 1.17 [1.04-1.30]) were associated with increased odds of nonroutine discharge; EBL was not (OR: 1.0 [1.000-1.001]). There was no relationship between nonroutine discharge and reoperation within 3 mo ($P = .249$), 6 mo ($P = .793$), or 1 yr ($P = .814$) of index procedure.

Multivariable Regression Modeling of Discharge Indicators

Controlling for fusion length and age, the following combination of preoperative patient-related and radiographic factors were responsible for 27.3% of the variation in discharge status

TABLE 2. Univariate Comparison of Demographic and Surgical Factors Between Home Discharge and Nonroutine Discharge Patient Groups

	Home discharge	Nonroutine discharge	P-value
Demographic comparison			
Age (yr)	59.3 ± 10.5	66.4 ± 8.5	<.001
Sex (% female)	62.5%	64.1%	.861
BMI (kg/m ²)	28.8 ± 7.5	31.0 ± 8.8	.162
CCI	0.91 ± 1.22	0.88 ± 1.32	.916
Surgical comparison			
Levels fused	7.3 ± 4.2	10.3 ± 4.8	<.001
EBL (cc's)	749 ± 841	1081 ± 934	.044
Operative time (min)	476 ± 271	519 ± 403	.477
Approach			
Anterior	20.4%	5.0%	.025
Posterior	46.9%	55.0%	.390
Combined	32.7%	40.0%	.411
Osteotomy			
Any	52.0%	65.0%	.164
Smith-Petersen	24.5%	20.0%	.571
Pedicle subtraction	10.2%	25.0%	.025
Vertebral column resection	1.0%	12.5%	.003
Decompression	50.0%	72.5%	.016

($R^2 = 0.273$, $P < .001$): gait impairment ($\beta = 0.081$), C0 Slope ($\beta = 0.015$), and McGregor's Slope ($\beta = 0.016$).

Myelopathy Outcomes by Discharge Group

At BL and 3-mo intervals, 89.9% and 77.5% of patients had available mJOA information. Nonroutine discharge patients presented with more severe myelopathy, as assessed by mJOA score (home: 14.0 ± 2.8 vs nonroutine: 12.8 ± 2.4 , $P = .037$). Assessed by specific subsection of the mJOA questionnaire, nonroutine discharge patients presented with more severe myelopathic motor dysfunction in the lower extremities (home: 5.0 ± 1.4 vs nonroutine: 3.9 ± 1.1 , $P < .001$). The groups did not differ in BL myelopathic dysfunction of the upper extremities ($P = .238$), sensory loss ($P = .783$) or sphincter dysfunction ($P = .805$). At 3-mo postoperative, nonroutine discharge patients continued to show inferior overall mJOA (home: 14.7 ± 2.5 vs nonroutine: 12.7 ± 2.9 , $P = .001$), and myelopathic lower-extremity (home: 5.3 ± 1.6 vs nonroutine: 4.0 ± 1.7 , $P < .001$) scores. Patient groups did not differ in 3-mo upper-extremity ($P = .057$), sensory loss ($P = .783$), or sphincter ($P = .084$) scores.

Patient-Reported Outcomes by Discharge Group

Overall, 95 (68.8%) of included patients had available 1-yr postoperative HRQL follow-up, with no difference between discharge groups in rates of 1-yr HRQL follow-up (home: 68.3%, nonroutine: 70.0%, $P = .851$). Nonroutine discharge patients showed inferior EQ-5D outcomes at 1-yr postoperative follow-up (home: 0.79 ± 0.07 vs nonroutine: 0.76 ± 0.08 , $P = .034$), despite no significant difference in BL EQ-5D scores between discharge groups (home: 0.73 ± 0.07 vs nonroutine: 0.73 ± 0.06 ,

$P = .946$). There were no significant differences in NDI scores between patient groups at BL (50.2 ± 18.5 vs 46.2 ± 16.4 , $P = .237$) or 1-yr (35.6 ± 20.6 vs 40.0 ± 20.6 , $P = .337$) follow-up.

Case Example

Preoperative and postoperative lateral radiographs of a patient discharged home and a patient discharged to a skilled nursing facility (Figure 4A and 4B, respectively). Preoperatively, the patient in Figure 4B presented with a number of factors associated with increased odds of nonroutine discharge, including age <59 yr (home: 50 yr vs nonroutine: 61 yr), and more severe upper-cervical malalignment (C2 Slope, home: 19° vs nonroutine: 71°), TS-CL (Home: 25° vs Nonroutine: 74°), and cSVA (home: 17 mm vs nonroutine: 45 mm). The nonroutine discharge patient also underwent a longer fusion (home: 7 levels vs nonroutine: 8 levels) that met the threshold associated with increased odds of nonroutine discharge (≥ 8 levels) identified in this study.

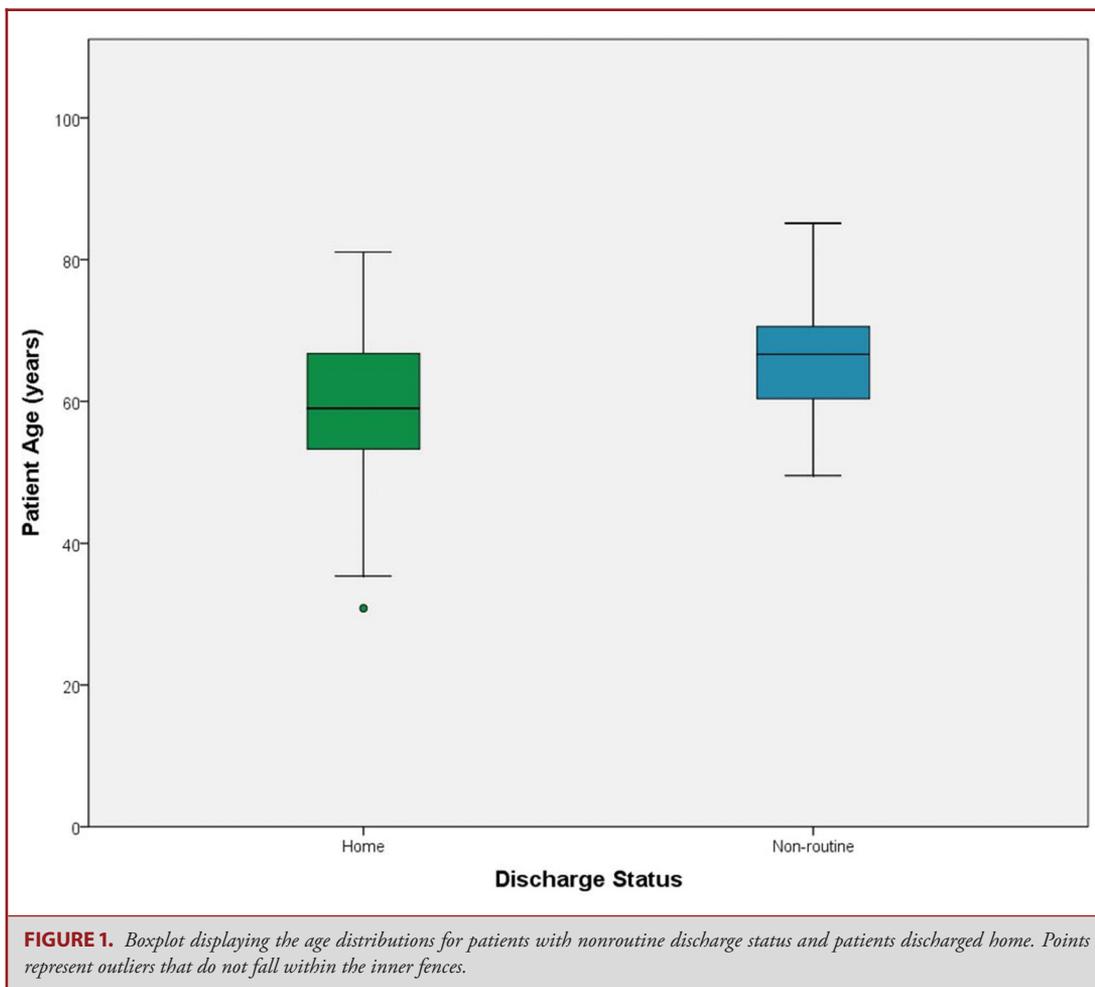
DISCUSSION

Cervical spine surgery is increasingly common in the United States, with multiple studies showing a marked increase in the rate of surgery for degenerative cervical pathologies over the past few decades.^{15,16} Despite advancements in surgical technique and the standardized classification of CD, CD-corrective surgery remains challenging due to the disease's complex etiology and a typically heterogeneous patient population.^{1,17} While clinical outcomes following CD-corrective surgery are generally favorable, small-scale studies report postoperative nonroutine discharge rates as

TABLE 3. Top Patient-Related, Procedural, Complication, and Radiographic Factors Associated With Nonroutine Discharge Following Corrective Surgery for CD

Overall rank	Factor associated with nonroutine discharge	Groups compared: 1 (N) vs 2 (N)	Proportion of discharge to nonroutine		P-value	OR	95% Confidence interval	
			Group 1	Group 2			Lower	Upper
BL patient-related predictors								
2	Gait impairment	Yes (31) vs no (106)	58.1%	20.8%	P < .001	5.29	2.25	12.42
7	SWAL communication ≤ 52	≤ 52 (19) vs ≥ 53 (118)	57.9%	24.6%	P = .005	4.22	1.55	11.50
8	Age ≥ 59 yr	≤ 58 yr (90) vs ≥ 59 yr (48)	12.5%	37.8%	P = .003	4.25	1.63	11.05
Procedural predictors								
12	Levels fused ≥ 8	≤ 7 (61) vs ≥ 8 (69)	17.3%	45.9%	P = .001	4.03	1.81	8.98
Complication predictors								
5	Number of complications ≥ 2	≤ 1 (39) vs ≥ 2 (99)	20.2%	51.2%	P < .001	4.16	1.87	9.22
6	Postoperative LOS ≥ 6 d	≤ 5 d (68) vs ≥ 6 d (70)	15.7%	42.7%	P < .001	3.99	1.79	8.91
9	EBL ≥ 900 cc	≤ 899 (88) vs ≥ 900 cc (50)	19.3%	46.0%	P = .001	3.56	1.65	7.67
13	Stay in surgical ICU	Yes (90) vs no (47)	38.9%	10.6%	P = .001	5.35	1.93	14.82
16	Any neurologic complication	Yes (30) vs no (108)	46.7%	24.0%	P = .018	2.76	1.19	6.41
BL radiographic predictors								
1	C1 Slope ≥ 14°	< 14° (107) vs ≥ 14° (23)	21.5%	69.6%	P < .001	8.35	3.07	22.71
3	C2 Slope ≥ 57°	< 57° (113) vs ≥ 57° (23)	21.2%	65.2%	P < .001	6.95	2.64	18.33
4	T5-CL ≥ 57°	< 57° (111) vs ≥ 57° (21)	21.6%	61.9%	P < .001	5.89	2.19	15.85
10	Apex of primary driver ≥ C7	≤ C6 (75) vs ≥ C7 (60)	17.3%	45.0%	P = .001	3.90	1.78	8.56
11	C2-S1 ≤ -22°	≤ -22° (27) vs > -22° (96)	55.6%	20.8%	P = .001	4.75	1.92	11.74
14	C0 Slope ≥ -0.66°	< -0.66 (80) vs ≥ -0.66° (47)	18.7%	48.9%	P < .001	4.15	1.86	9.26
15	cSVA ≥ 40 mm	< 40 mm (67) vs ≥ 40 mm (67)	13.4%	41.8%	P < .001	4.63	1.97	10.87
17	T2-T12 Kyphosis ≤ -51°	≤ -51° (54) vs > -51° (82)	46.3%	18.3%	P = .001	3.85	1.78	8.35
18	McGregor's Slope ≥ 1.9°	< 1.9° (58) vs ≥ 1.9° (56)	15.5%	42.7%	P = .002	4.08	1.68	9.91

OR from binary logistic regression indicate odds of nonroutine discharge for each factor at the factor's respective cut-off point. ICU = intensive care unit.



high as 40%.¹⁸ Nonroutine discharge, including discharge to subacute care and inpatient rehab, has previously been associated with increased cost-of-care following spine surgery, and may place patients at higher risk for hospital-acquired conditions like nosocomial infection.^{7,19} The present study aimed to identify independent factors associated with nonroutine discharge, as such indicators can be used to improve preoperative patient counseling and risk stratification.

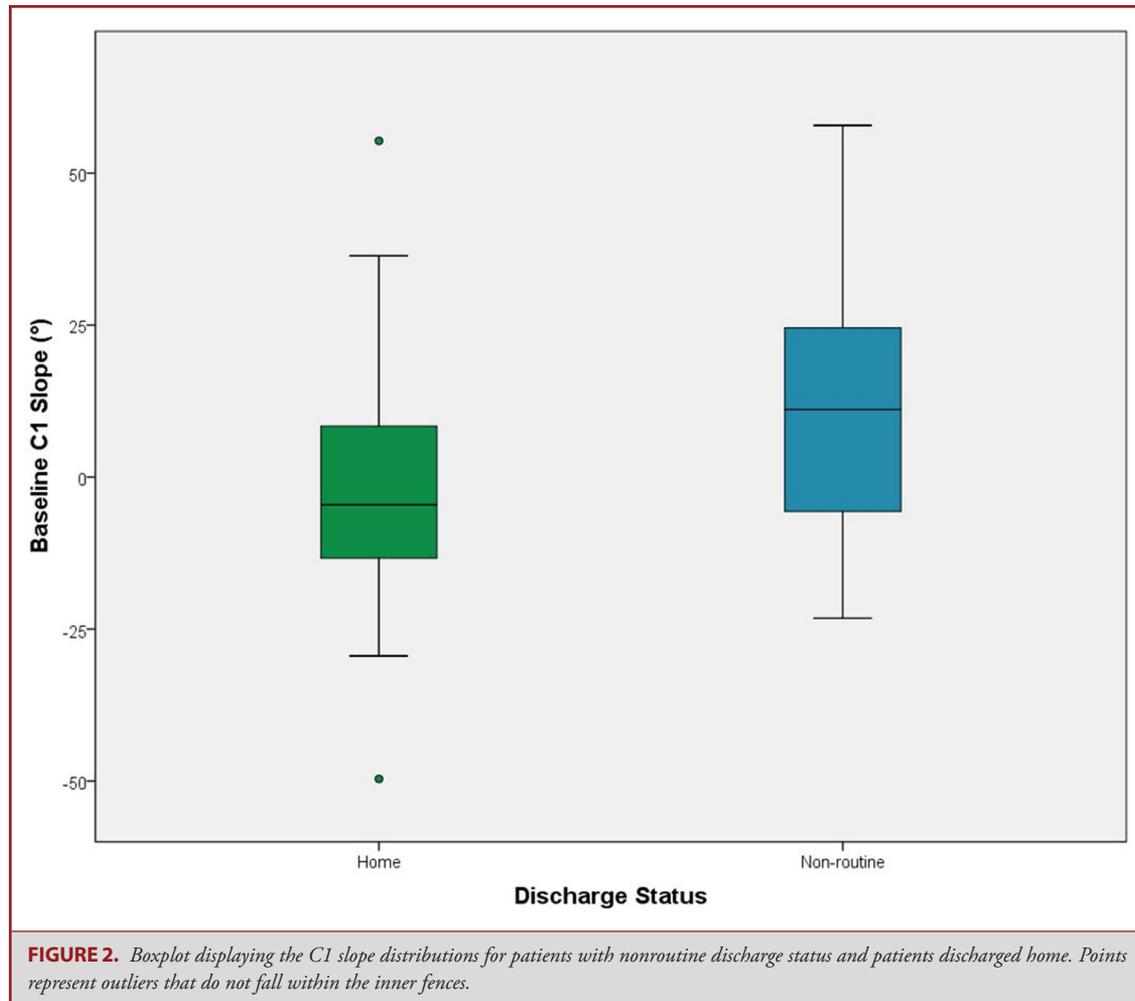
Key Results

Factors associated with nonroutine discharge following CD-corrective surgery are undercharacterized in the literature, primarily due to the fact that CD has only recently been classified as a distinct clinical entity.¹⁷ Our study identified multiple surgical and patient-related variables associated with nonroutine discharge following CD-corrective surgery, the strongest of which were preoperative cervical and upper-cervical malalignment. Controlling for the covariates of age and fusion length, multivariable regression analysis further showed upper-cervical

malalignment (as assessed by C0 Slope and McGregor's Slope) as being associated with nonroutine discharge. Assessing the relationship between the radiographic alignment and discharge destination is particularly novel, as similar investigations in the literature base their analyses on large nationwide databases lacking in radiographic granularity.^{20,21} Additionally, investigating cervical sagittal alignment as associated with nonroutine discharge is especially important in the context of CD, as severe preoperative cervical and upper-cervical sagittal malalignment have previously been correlated with inferior outcomes following surgical CD correction.^{4,22} In suggesting a relationship between severe cervical malalignment and discharge destination, our results allow for better-informed preoperative counseling for high-risk patients regarding their care after surgery.

Interpretation

While our study identified statistically meaningful cut-offs at which various radiographic parameters were associated with nonroutine discharge, this does not necessarily mean that the cutoffs should be interpreted as strict indicators. Statistical



significance does not always equate to clinical relevance; for example, a patient with a cSVA of 39 mm does not necessarily have substantially lower odds of nonroutine discharge as compared to a similar patient with a cSVA of 4 mm. Indeed, when assessed as continuous variables, the radiographic factors assessed in this study were still associated with discharge destination, demonstrating a trend of increasing odds of nonroutine discharge with increasing severity of radiographic deformity. Furthermore, given previous research showing strong correlations between upper-cervical and subaxial radiographic alignment, it is possible that some of these radiographic predictors are acting as moderator variables for other independent predictors of discharge.²³ In light of this, we suggest that the radiographic indicators and respective cutoffs identified in our study should be interpreted as tools for use in the greater context of spinopelvic alignment to predict nonroutine discharge after CD-corrective surgery.

It is important to note that when using OR as a measure of association with discharge status, one must take into account

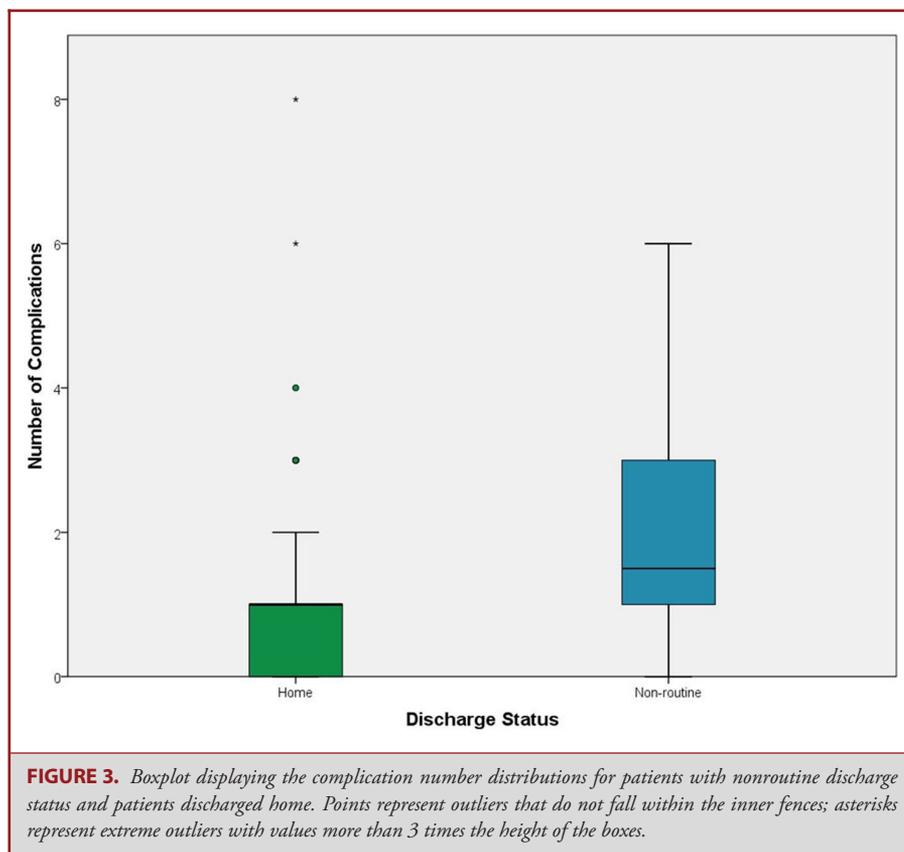
the proportion of patients experiencing nonroutine discharge. The risk of nonroutine discharge and the odds of nonroutine discharge are not necessarily interchangeable. Specifically, as the probability of nonroutine discharge increases, the odds and risk ratio diverge, with the corresponding OR growing larger than the corresponding risk ratio.²⁴ The upshot is a more extreme OR, which should be taken into account when interpreting the results of factors like gait impairment, which in our analysis had an OR of 5.29 but a relative risk ratio of 1.94 (95% CI: 1.15-3.26). Still, this analysis is a logistic regression-based case-control study in which patients were grouped by their outcomes, not their exposures. As such, the use of OR as a measure of association is justified as absolute risk, and therefore relative risk cannot be calculated accurately.^{25,26}

Previous literature on discharge destination following spine surgery has primarily focused on patients undergoing lumbar decompression or fusion.^{8,21} One of the few studies investigating indicators of discharge location following cervical surgery also showed patient age, preoperative functional status, and operative

TABLE 4. Top Radiographic Factors Associated With Nonroutine Discharge Following Corrective Surgery for CD

Continuous indicator of nonroutine discharge	P-value	OR	95% Confidence interval	
			Lower	Upper
C1 Slope	$P < .001$	1.05	1.02	1.07
C2 Slope	$P = .003$	1.03	1.01	1.05
TS-CL	$P = .008$	1.03	1.01	1.06
C2-S1	$P = .017$	0.98	0.961	0.996
C0 Slope	$P = .001$	1.05	1.02	1.08
cSVA	$P = .006$	1.03	1.01	1.05
T2-T12 Kyphosis	$P = .024$	0.98	0.961	0.997
McGregor's Slope	$P = .008$	1.04	1.01	1.07

OR from binary logistic regression indicate associated odds of nonroutine discharge for each continuous radiographic parameter.



time as associated with patient discharge to a facility other than home.⁹ Our results substantiate these reports, similarly demonstrating age ≥ 59 yr, ≥ 8 level fusion, and multiple complications as indicative of nonhome discharge. As the literature also suggests a strong correlation between age and frailty, future research should investigate frailty as an indicator of nonroutine discharge in operative CD patients.²⁷

In addition to the factors mentioned above, our results show an increased risk of nonroutine discharge for patients with primary

structural drivers of CD below C7. These results were based upon a recent investigation of 73 CD patients, which similarly showed inferior postoperative outcomes for patients with CD drivers in the thoracic spine.²⁸ Specifically, patients with thoracic drivers of deformity showed no improvement in HRQL at the 1-yr postoperative interval and were significantly more likely to have persistent severe TS-CL deformity. While cervical sagittal alignment is certainly an important consideration in the preoperative assessment of CD, the interdependence of the cervical,



thoracolumbar, and lumbopelvic curves in the context of CD is gaining increased attention in the literature.^{29,30} The results of the present study further emphasize the importance of the full spine, not just the cervical region, in influencing outcomes following CD-corrective surgery.

Although discharge to subacute care may be a necessary part of the recovery process for patients undergoing complex CD-corrective surgery, efficient allocation of health care resources necessitates effective preoperative risk stratification. Indeed, while the nationwide average for hospital LOS has decreased over the past few decades, discharges to postacute care facilities have increased by nearly 50%.³¹ In helping identify patients with

increased odds of nonroutine discharge, the present study serves as a jumping-off point for preoperative patient–surgeon discussions about discharge status and expectations for recovery. Hopefully, this will allow patients, patient families, insurance providers, and postacute care facilities to better plan for the likelihood of requiring additional health care services after surgery.

Limitations

An important limitation of this analysis was our inability to account for social and patient-related factors, such as family support system, social history, and insurance status, which could all potentially affect the discharge destination. Decisions

regarding patient discharge destination following surgery are multi-disciplinary, often taking into account guidance from physical and occupational therapists, as well as social factors like caregiver status and community support. As these variables were not included in the database, we were unable to adequately control for these potentially significant confounders. Given this limitation, it is important to emphasize that our findings present factors correlated with nonroutine discharge; they do not speak to causative factors.

Additionally, small sample size reduces the statistical power of our findings and raises the possibility of spurious predictors due to statistical noise. The small sample size is reflected in the relatively wide confidence intervals of our regression analyses. Our results likely reflect a spectrum of variables associated with discharge status: those actually associated with nonroutine discharge, those serving as moderator variables for other factors, and those incorrectly identified as being associated with nonroutine discharge because of small sample size. Future large-scale studies with more statistical power to control for bias are needed to further confirm the findings of this study. Lastly, the present analysis lacks external validity, and thus the generalizability of our conclusions to a broader CD patient population is uncertain. Our results reflect experienced deformity surgeons with specific practice patterns treating patients at tertiary spine centers, and as such, the results may not be applicable to all spinal surgeons in all settings. Despite this, the multicenter database design allowed for enrollment of patients with a wide range of CD presentations from 13 surgical sites across the United States, lending increased generalizability to our findings.

CONCLUSION

Severe preoperative cervical and upper-cervical malalignments, including C1 Slope $> 14^\circ$, TS-CL $\geq 57^\circ$, and cSVA ≥ 40 mm, were among the strongest indicators of nonroutine discharge following surgical correction of CD. Patient-related factors such as advanced age and preoperative gait impairment as well as fusion length and number of in-hospital complications were also associated with nonroutine discharge, and they should be taken into account to improve current preoperative risk-stratification strategies. Future large-scale studies controlling for covariates are necessary to confirm these findings; however, in identifying potential indicators of nonhome discharge following CD-corrective surgery, this study may serve as a resource for patients and surgeons to better estimate the likelihood of requiring additional health care services after surgery.

Disclosures

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