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Clinical Study

Early intervention in cauda equina syndrome associated with better outcomes: a myth or reality? Insights from the Nationwide Inpatient Sample database (2005–2011)

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Abstract

BACKGROUND CONTEXT: Evidence-based consensus on timing to surgical decompression following symptom onset in patients with cauda equina syndrome (CES) is limited or widely debated.
PURPOSE: This study aimed to investigate whether timing to intervention in the management of patients with CES has an impact on outcomes.
STUDY DESIGN/SETTING: This is a retrospective cohort study.
PATIENT SAMPLE: The patient sample included 4,066 adult patients with CES registered in the Nationwide Inpatient Sample database (2005–2011) and undergoing elective decompression surgery.
OUTCOME MEASURES: The outcome measures are inpatient mortality, unfavorable discharge (discharge to rehabilitation), prolonged length of stay (LOS>75th percentile), and high hospital charges in patients undergoing decompression for CES.
METHODS: The patients were stratified into three categories based on timing to surgical intervention: (1) within 24 hours (n=1,846, 45.6%); (2) between 24 and 48 hours (n=1,080, 26.6%), and (3) beyond 48 hours (n=1,130, 27.8%). Multivariable logistic regression fitted with generalized estimating equations using the sandwich variance-covariance matrix estimator to account for the clustering of similar outcomes within hospitals was used to examine the association of timing to surgical intervention categories with binary primary end points. For metric end points (charges), we used the ordinary least squares model to test the effect of timing to intervention.
RESULTS: The mean age of the cohort was 50.19±17.55 years and 41% were female. In comparison to patients operated within 24 hours, increased likelihood of inpatient mortality (odds ratio [OR]: 3.61, 95% confidence interval [CI]: 1.32–9.85, p=.012), unfavorable discharge (OR: 2.23, 95% CI: 1.87–2.66, p<.001), prolonged postsurgical LOS (OR: 1.76, 95% CI: 1.44–2.14, p<.001), and high hospital charges (OR:1.92, 95% CI: 1.81–2.05, p<.001) were observed in patients operated on over 48 hours since admission. Likewise, patients with incomplete CES with intervention beyond 48 hours had higher odds for unfavorable discharge (OR: 2.51, 95% CI: 1.99–3.17, p<.001), prolonged postsurgical LOS (OR: 1.73, 95% CI: 1.35–2.20, p<.001), and high hospital charges (OR: 1.94, 95% CI: 1.79–2.10, p<.001). Likewise, patients with complete CES with interventions beyond 48 hours had higher odds for unfavorable discharge (OR: 1.86, 95% CI: 1.41–2.45, p<.001), prolonged postsurgical LOS (OR: 2.06, 95% CI: 1.53–2.77, p<.001), and high hospital charges (OR: 1.39, 95% CI: 1.15–1.68, p<.001).

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CONCLUSIONS: Early intervention in CES, regardless of the subtype (complete or incomplete), has higher likelihood of improved inpatient outcomes. The odds of getting better were higher, however, with incomplete CES. The timing of intervention did not seem to matter in traumatic CES as compared with degenerative etiology. Prospective randomized controlled trials may further help elucidate the impact of early intervention on outcomes in patients with CES.

Keywords: Cauda equina syndrome; Degenerative cauda equina syndrome; Discharge disposition; Early intervention; Hospital cost; Inpatient morbidity; Lumbar decompression; NIS database; Outcomes; Traumatic cauda equina syndrome

Introduction

Cauda equina syndrome (CES) comprises a myriad of signs and symptomatology including, but not limited to, lower back pain, radicular pain, saddle anesthesia, bowel or bladder incontinence, or sexual disturbances [1]. Numerous attempts in defining and understanding this clinical syndrome have been made. In addition to subjective symptomatology secondary to insult to the lumbosacral neural elements, the general consensus relies on some form of micturition disturbance as the key element in completing the syndrome [1–3]. For practical purposes, CES is categorized as incomplete or complete. Whereas the former comprises patients with micturition disturbances with no frank urinary retention, the latter comprises patients with painless urinary retention or overflow incontinence [1,4,5].

CES draws interest to not only neurosurgeons and orthopedic surgeons as a “surgical emergency” but also healthcare attorneys globally. CES is well known for having a low incidence among patients with lower back pain who present to the emergency department, albeit associated with disproportionately higher medicolegal claims and settlements [6,7]. Legal litigations governing CES are in most instances not based on overall outcomes but over timing of intervention. However, limited literature exists defining the timing for surgery in these patients. The available data are equally limited because of single-institutional data, which lack generalization. To our knowledge, no data exist from randomized controlled trials evaluating the impact of timing to intervention on outcomes in these patients. Historically, Ahn et al. proposed the concept of “within 48 hours” intervention as a dictum for improved outcomes in these patients [2]. However, this has been widely debated. A recent review depicted no significant difference in urinary outcomes between early (before 48 hours) vs. delayed (after 48 hours) intervention [1].

Despite these efforts in defining the role of timing to intervention for improved outcomes in patients with CES, the small sample size limits sufficient power to generalize conclusions [1,2,8]. Results from single-institutional studies are subjected to inherent selection bias [5,7]. To the best of our knowledge, no previous studies have used the Nationwide Inpatient Sample (NIS) database or any administrative cohort to elucidate the significance of timing to intervention as it relates to outcomes in patients with CES. The present study investigates outcomes in patients with CES who underwent surgical decompression across three cohorts of timing to intervention: within 24 hours, 24–48 hours, and beyond 48 hours using the NIS database.

Methods

Data source

We used the NIS database as the data source for the present study [9]. The NIS is developed by the Agency of Healthcare Research and Quality (Rockville, MD) as a part of the Healthcare Cost and Utilization Project. Containing non-identifiable discharge data cumulative of over 7 million inpatient stays for each year, from over 1,000 participating hospitals, the NIS is the largest inpatient cohort assembled in the United States that entails all-payer. The database is designed to represent 20% random, stratified sampling across non-federal US hospital discharges [10]. The clinical data in the NIS are catalogued into relevant categories of nearly 14,000 diagnoses and over 3,900 procedures using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes [10]. Further description of the database can be accessed at https://www.hcup-us.ahrq.gov/nisoverview.jsp.

Cohort definition and data cleaning

For the study years (2005–2011), the NIS database was queried to identify adult patients (≥18 years) with diagnoses of CES (ICD-9-CM diagnosis codes 344.6, 344.60, 344.61, and 952.4) who underwent surgical decompression (ICD-9-CM procedure codes 03.0, 03.01, 03.09, 03.4, 03.53, 80.5, 80.5x, 84.5, 84.6, 84.60, 84.64, 84.65, 84.68, 84.80, 84.82, and 84.84) (Fig. 1). These coding definitions, employed to define a cohort of patients with CES, have been described previously in the literature [11,12]. Patients with CES who were managed conservatively (without a surgical intervention) and those with elective admissions were excluded. The timing to surgical intervention for CES was computed for each of the identified cases. To eliminate any biases relating to miscoding in timing to intervention in the extracted cohort, patients with negative values on the day of surgical intervention (minus 2 and 1) were excluded. Patients were subsequently categorized as having a surgical decompression within 24 hours (procedure day=0), between 24 and 48 hours (procedure day=1) and those beyond 48 hours (procedure day≥2).

EVIDENCE & METHODS

Context
In this retrospective database analysis, the authors aimed to assess whether timing of surgery in cauda equina syndrome (CES) impacted outcomes.

Contribution
They found that surgery later than 24 hours correlated with discharge to rehabilitation facilities, longer postsurgical length of stay, and higher costs.

Implications
The study serves primarily as a nidus for further investigation. It is unclear that the outcomes measured are good proxies for bowel, bladder, or motor function. It is unclear whether they predict long-term outcomes. Quite simply, the paucity of relevant CES-specific data in the database requires faith in proxies and statistical gymnastics that would be unacceptable in a prospective design.

—The Editors

Outcome variables

The primary outcome variables investigated were inpatient mortality, unfavorable discharge, postsurgical length of stay (LOS), and hospitalization charges. These outcomes, although surrogate, provided a baseline estimation of surgical outcome and were intuitive of the inpatient care received. Moreover, these primary end points were particularly chosen based on the design of the data source used. We investigated these primary end points for all patients with CES. Additionally, we also performed an independent subgroup analysis for patients with complete CES and incomplete CES, as well as CES patients with degenerative and traumatic etiologies. The secondary outcomes assessed were postoperative complications including pulmonary embolism (PE), deep venous thrombosis (DVT), and wound infections.

To evaluate true postsurgical LOS, the day of surgical intervention was subtracted from the total inpatient LOS. The computed postsurgical LOS minimized the interinstitutional variability and other oblivious factors in the operative scheduling times. For the years studied, all analyses pertaining to hospital charges were performed following inflation

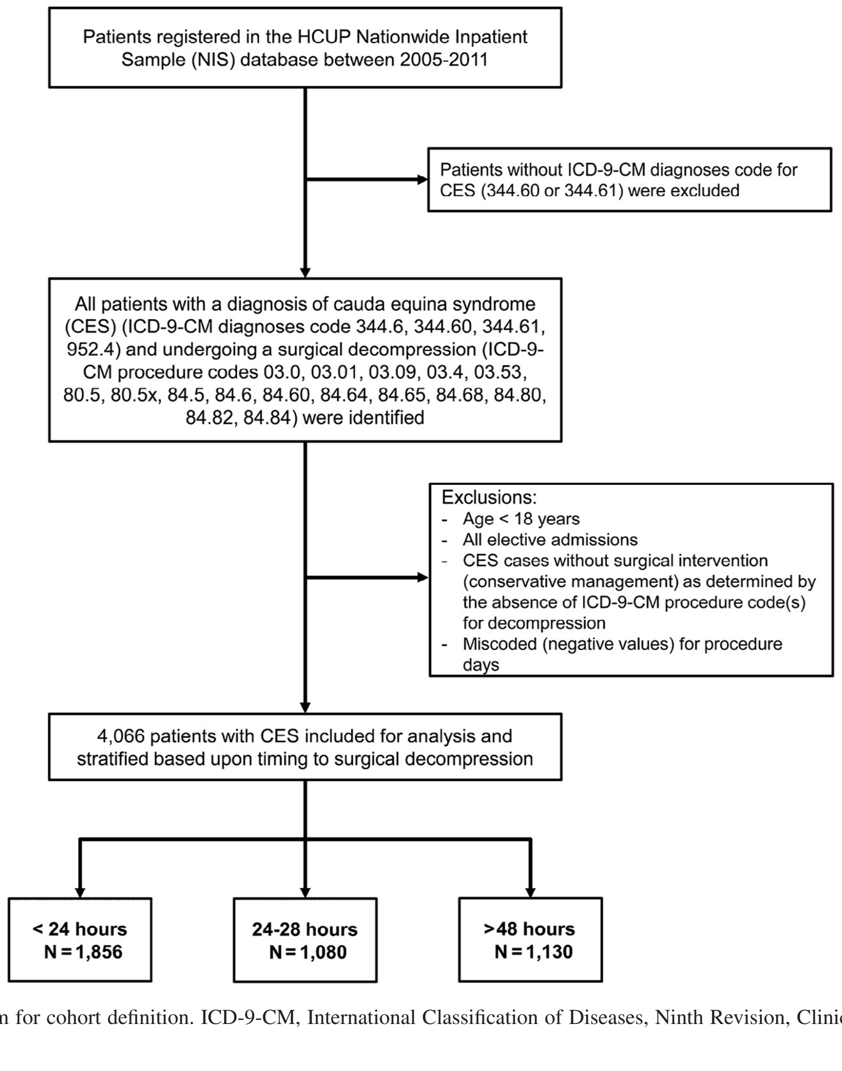


Fig. 1. Algorithm for cohort definition. ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

adjustments to 2015 US dollar amounts using the national consumer price index [13]. Postsurgical LOS and discharge disposition were dichotomized. Patients with postsurgical LOS above the 75th percentile were labeled as having "prolonged postsurgical LOS," whereas discharge disposition was categorized as routine (home and home health care) and unfavorable (other than routine including transfer to a short-term hospital, skilled nursing facility, intermediate care, or rehabilitation). Based on the definitions described in the literature [14–16], we selected appropriate ICD-9-CM coding definitions to label patients with CES with a diagnosis of neurogenic bladder (344.61), bowel (787.6 and 787.60), and bladder incontinence (596.54, 788.3, 788.30, 788.34, 788.38, and 788.39) as having complete CES, whereas the remainder were classified as having incomplete CES.

Exposure variables

The primary exposure variable of interest was timing to surgical intervention, categorized as less than 24 hours, 24–48 hours, and beyond 48 hours (Supplementary Table S1). Surgical intervention within 24 hours was set as the reference value. Patient demographics encoded in the NIS and used as exposures included age, sex, race (African Americans and others with reference to Caucasians), primary payer (Medicaid, private including HMO, and others with reference to Medicare), and median income quartile based on the zip code of residence (highest, third, and second quartiles with reference to the lowest quartile). To avoid aberrant coefficients in the regression models, small categories of selected exposures, including race and payer, were coalesced. Patients belonging to Hispanic (8.6%), Asian (2.8%), other (2.9%), or Native American (0.6%) race were designated into "other" race, whereas self (8.2%) or no-charge (1.0%) or other payer (10.3%) was computed into "other" payer. The day of admission (weekend with reference to weekday) was also adjusted in the regression analysis.

Adjustment for clinical comorbidities was achieved by quantifying the effect of medical comorbidities by stratifying using the Charlson Comorbidity Index (CCI) [17]. The CCI scores were computed with the method revised by Deyo et al. [18] using the ICD-9-CM codes [19]. Relevant to our analysis, we adjusted for the presence of the CES status (complete CES with reference to incomplete CES). Lastly, hospital-specific information adjusted in the analyses included bed size, academic status and location, and geographic region.

Statistical analysis

Categorical variables across the three timing to intervention groups were tabulated as frequencies and proportions, and compared using the Pearson χ^2 test. Metric variables are tabulated as mean±standard deviation or median (interquartile range), with differences in the means across the groups evaluated using one-way analysis of variance or non-parametric Kruskal-Wallis as appropriate. To assess the multicollinearity between categorical variables, we used the phi (Φ) and the Cramer V coefficients, biserial correlation for metric and categorical variables, and the Pearson correlation between metric variables.

Before constructing regression models, we assessed the predefined exposures for any *missing* values. The proportion of missing data for gender (0.2%), race (10.9%), payer (0.4%), income quartiles (2.2%), hospital bed size (0.8%), and location and teaching status (0.8%) was determined. Patterns of these missing values demonstrated the *missing* to be completely at random. To deal with missing values, we preferred a model-based multiple-imputation technique because of its enhanced performance over alternative approaches [20–24]. To prevent data shrinkage, traditional deletion methods like list or pairwise deletion were avoided [25]. Single-imputation technique to replace the missing value with a predicted value using mean substitution, and cold- and hot-deck imputations are limited as these methods ignore uncertainty and undermine the variance [26,27]. Based on the existing variables, five iterations were performed to generate five imputed datasets that were combined to generate a pooled dataset in the regression analyses with no missing values.

Multivariable log-binomial and ordinary least squares (OLS) models were constructed with imputed datasets to examine the association of timing to intervention for each of the defined primary end points as appropriate. Age and CCI scores were modeled as metric variables, whereas all others were categorical. Regression diagnostics was performed for each of the models. A variance inflation factor of <5 was set permissible for inclusion. To account for the clustering of similar outcomes within hospitals that could falsely contribute to inflated estimates of statistical significance for regression coefficients, we fitted all log-binomial models using generalized estimating equations [28]. The Huber and White sandwich variance-covariance matrix estimator was introduced [29–31]. The derived empirical standard errors were used to compute the 95% confidence intervals (CIs) of the estimates, with adjustment for clustering by hospital. Validity assessments of the derived associations for the exposure variables were performed using the non-parametric concordance index (c-statistics) for each of the models [32]. The Hosmer-Lemeshow goodness-of-fit test was employed to assess the model calibration. For all log-binomial models, interactions were tested (11×10/2=55 interactions in all), but none were accounted to be of significance at the threshold (0.001) set to correct for multiple testing. Further, none influenced the c-index by more than 0.5.

As numerical (Shapiro-Wilk test) and graphical (histograms, Q-Q plots, and stem-and-leaf plots) assessments of distribution of hospital charges demonstrated marked skewness and kurtosis, constructing an OLS model contributed to the heteroskedastic variance of errors. To combat this, we attempted transformation of hospital charges using several methods such as the natural logarithm (ln), square root, cube root, and inverse transformation techniques. The ln logarithmic transformation was deemed to bestow the best fit, following which an OLS model was constructed with all the above exposures to assess the effect of timing to intervention on hospital charges. For non-binomial categories, we created dummy variables. Regression diagnostics, including analyses of residuals, estimation of coefficient of determination (R^2), and assessment of collinearity via evaluating the tolerance and variance inflation factors for all OLS models, was performed. The estimates for timing to intervention for metric outcome (hospital charges) were back-transformed for the purpose of reporting the percentage change (%Δ) with the defined reference category of the primary exposure or with odds ratios (ORs) as appropriate.

As a part of sensitivity analyses, we evaluated the derived estimates for timing to intervention and corrected for c-statistics using 1,000 bootstrapped replacement samples stratified upon nested patient clusters within hospitals for each of the primary outcomes. The obtained estimates were similar to our primary analysis and therefore were not reported separately.

The current analysis, based on over 4,000 patients, has 80% power at a type I error rate of 5% to detect differences in mortality across patients with CES categorized upon timing to surgical decompression (within 24 hours vs. post 24 hours) as small as 0.7% All statistical analyses were performed using commercially available SPSS version 22.0 (IBM, Armonk, NY, USA), Stata 14.0 MP (StataCorp, LP, College Station, TX, USA), and Minitab 17 (Minitab 9 Inc., State College, PA, USA).

Results

Patient demographics and clinical characteristics

During the selected study period, 4,066 patients registered in the NIS database underwent non-elective surgical intervention for CES. The mean age of the cohort was 50.19±17.55 years (median: 48 years) and 42% were female (Table 1). Of these patients, approximately 46% underwent a surgical decompression within 24 hours (n=1,856), 26% (n=1,080) between 24 and 48 hours, and 28% beyond 48 hours (n=1,130). Approximately four-fifths of these admissions (79%) occurred during the weekday. For patients being operated during the same day admission (<24 hours), 78% were admitted during the weekday. With reference to African Americans (8% vs. 12.5%), Caucasians (76% vs. 68%) had higher proportions of interventions within 24 hours in comparison to the post-48-hour group. Higher proportions of privately insured patients (49%) were operated on within 24 hours compared with those having Medicare (18%) and Medicaid (12%). Approximately 39% of the patients had complete CES with bowel and bladder dysfunctions. A detailed overview of the demographic and clinical profiles of the study cohort is depicted in Table 1. Marked differences across the three groups were noted in terms of age (46 years vs. 49 and 57 years, p<.001), insurance, particularly those funded by Medicare (18% in the <24-hour group vs. 24% and 39%, p<.001), private insurance (49% in the <24-hour group vs. 43% and 31%, p<.001), mean hospital charges (US$61,636 in the <24-hour group vs. US$82,840 and US$ 137,941), and LOS (mean: 4.96 days in the <24-hour group vs. 6.40 and 12.66 days). Interestingly, patients receiving intervention within the 24-hour time frame had lower comorbidity as compared with those undergoing surgical decompression within 24–48 hours and beyond the 48-hour period (mean CCI score: 2.85 vs. 3.01 vs. 3,79, p<.001). These translated to lower proportions of cardiac comorbidities such as coronary artery disease (8.4% vs. 10.5% and 21.7%, p<.001), hypertension (32.8% vs. 38.1% and 50.6%, p<.001), and congestive heart failure (2.0% vs. 2.3% and 7.0%, p<.001); chronic obstructive pulmonary disease (10.9% vs. 11.3% and 15.3%, p<.001); coagulopathies (1.9% vs. 4.0% and 5.9%, p<.001); anemia (11.6% vs. 15.3% and 28.1%, p<.001); peripheral vascular disease (1.1% vs. 1.9% and 3.7%, p<.001); hypercholesterolemia (13.8% vs. 16.1% and 23.4%, p<.001); and diabetes (12.2% vs. 13.7% and 22.9%, p<.001). Despite the lower medical comorbidities seen in patients receiving early intervention for CES, a higher proportion of patients were observed to have developed complete CES in comparison to other groups (41.4% vs. 35.9% and 37.7%, p=.013). For the known causes of CES as deciphered via ICD-9-CM coding definitions, degenerative etiology contributed to over two-thirds of the cohort, followed by trauma (5.9%) and epidural abscess and Pott disease (2.5%).

Clinical outcomes

Overall, the observed clinical outcomes included 0.9% death, 38% unfavorable discharge, 25% high-end hospital charges (>75 percentile), 20% prolonged LOS (>75 percentile), 4.3% DVT, 2.6% PE, 3.5% acute renal failure, and 4.8% wound infections. In comparison to patients operated on the same day of admission, a significantly higher proportion of inpatient complications were observed in those operated on beyond 48 hours and between 24 and 48 hours for unfavorable discharge (56% and 35% vs. 28%, p<.001), high charges (45% and 22% vs. 15%, p<.001), prolonged postsurgical LOS (30% and 18% vs. 16%, p<.001), DVT (8.1% and 3.6% vs. 2.3%, p<.001), PE (4.1% and 2.5% vs. 1.7%, p<.001), and acute renal failure (8.5% and 2.0% vs. 1.3%, p<.001). (Table 2) A comparison of baseline patient characteristics and outcomes across different intervention times for patients with incomplete CES and complete CES is tabulated in Table 3. In patients with incomplete CES, late intervention is associated with a high proportion of mortality (2.1% vs. <1%, p=.001) and unfavorable discharge (55.2% vs. 23.4%, p<.001). Moreover, these patients are likely to have higher mean hospital charges (US$ 139,795 vs. US$ 58,474, p<.001) and postsurgical hospital stay (6.91 days vs. 4.42, p<.001). Likewise, a similar trend in outcomes resonated in patients with complete CES receiving late intervention with a significantly higher proportion having an unfavorable discharge disposition (57.9% vs. 35.5, p<.001), higher hospital charges (US$134,883 vs. 66,290), and LOS (8.50 days vs. 5.73 days,

Table 1
Demographic and clinical characteristics of patients registered in the NIS who underwent a surgical intervention for cauda equine syndrome between 2005 and 2011

Characteristics	Time to intervention <24 h N=1,856	24–48 h N=1,080	>48 h N=1,130	Overall N=4,066	p Value
Demographic characteristics					
Mean age±SD (y)	46.46±16.44	48.84±16.99	57.19±17.75	50.19±17.55	**<.001**
Female gender, n (%)†	759 (41.0)	481 (44.7)	465 (41.2)	1,705 (42.0)	.125
Race, n (%)†					
White	1233 (75.6)	753 (78.8)	702 (67.8)	2,688 (74.2)	**<.001**
African American	133 (8.0)	69 (7.2)	129 (12.5)	329 (7.5)	**<.001**
Hispanic	148 (9.1)	84 (8.8)	117 (11.3)	117 (11.3)	.099
Asian	50 (3.1)	21 (2.2)	43 (4.2)	43 (4.2)	**.043**
Others	68 (4.2)	28 (2.9)	45 (4.3)	45 (4.3)	.196
Income, n (%)†					
Lowest quartile	391 (21.5)	235 (22.1)	283 (25.7)	909 (22.9)	**.028**
Second quartile	421 (23.2)	243 (22.9)	250 (22.7)	914 (23.0)	.951
Third quartile	504 (27.8)	270 (25.4)	283 (25.7)	1,057 (26.6)	.290
Fourth quartile	499 (27.5)	314 (29.6)	285 (25.9)	285 (27.6)	.158
Primary payer, n (%)†					
Medicare	337 (18.2)	258 (24.0)	443 (39.3)	1,038 (25.6)	**<.001**
Medicaid	228 (12.3)	136 (12.7)	142 (12.6)	506 (12.6)	.961
Private	907 (49.1)	459 (42.7)	348 (30.9)	1,714 (42.3)	**<.001**
Self	152 (8.2)	102 (9.5)	79 (7.0)	333 (8.2)	.108
Others	224 (12.1)	120 (11.2)	114 (10.1)	458 (11.3)	.245
Teaching status, n (%)†					
Rural	77 (4.2)	50 (4.7)	28 (2.5)	155 (3.8)	**.020**
Urban non-teaching	622 (33.7)	421 (39.2)	416 (37.2)	1,459 (36.2)	**.008**
Urban teaching	1,145 (62.1)	603 (56.1)	673 (60.3)	2,421 (60.0)	**.007**
Bed size, n (%)†					
Small	122 (6.6)	67 (6.2)	73 (6.5)	262 (6.5)	**.921**
Medium	381 (20.7)	221 (20.6)	209 (18.7)	811 (20.1)	.395
Large	1,341 (72.7)	786 (73.2)	835 (74.8)	2,962 (73.4)	.470
Region, n (%)					
Northeast	386 (20.8)	255 (23.6)	220 (19.5)	861 (21.2)	.052
Midwest	302 (16.3)	171 (15.8)	181 (16.0)	654 (16.1)	.951
South	657 (35.4)	361 (33.4)	412 (36.5)	1,430 (35.2)	.309
West	511 (27.5)	293 (27.1)	316 (28.0)	1,120 (27.6)	.903
Admission day					
Weekday	1440 (77.6)	902 (83.5)	878 (77.7)	3,220 (79.2)	**<.001**
Weekend	416 (22.4)	178 (16.5)	252 (22.3)	846 (20.8)	**<.001**
Hospital charges (US$)‡					
Mean	61,636	82,840	137,941	88,812	**<.001***
Median (IQR)	40,137 (49,752)	52,745 (68,585)	97,401 (113,961)	54,132 (78,260)	
Clinical characteristics, n (%)					
CAD	155 (8.4)	113 (10.5)	245 (21.7)	513 (12.6)	**<.001**
COPD	200 (10.8)	122 (11.3)	173 (15.3)	495 (12.2)	**.001**
CRF	84 (7.4)	35 (1.9)	23 (2.1)	142 (3.5)	**<.001**
Hypercholesterolemia	256 (13.8)	174 (16.1)	264 (23.4)	694 (17.1)	**<.001**
Smoking	485 (26.1)	265 (24.5)	243 (21.5)	993 (24.4)	**.017**
Obesity	266 (14.3)	156 (14.4)	158 (14.0)	580 (14.3)	.947
Alcohol abuse	42 (2.3)	26 (2.4)	43 (3.8)	111 (2.7)	**.032**
DM	227 (12.2)	148 (13.7)	259 (22.9)	634 (15.6)	**<.001**
PVD	21 (1.1)	20 (1.9)	42 (3.7)	83 (2.0)	**<.001**
Anemia	215 (11.6)	165 (15.3)	318 (28.1)	698 (17.2)	**<.001**
Coagulopathy	35 (1.9)	43 (4.0)	67 (5.9)	145 (3.6)	**<.001**
Hypertension	608 (32.8)	411 (38.1)	572 (50.6)	1,591 (39.1)	**<.001**
CHF	37 (2.0)	25 (2.3)	79 (7.0)	141 (3.5)	**<.001**
Charlson Comorbidity Index					
Mean	2.85	3.01	3.79	3.15	**<.001***
Low (0–2)	970 (52.3)	560 (51.9)	415 (36.7)	1,945 (47.8)	
Moderate/high (≥3)	886 (47.7)	520 (48.1)	715 (63.3)	2,121 (52.2)	

(*Continued*)

Table 1
(*Continued*)

Characteristics	Time to intervention <24 h N=1,856	24–48 h N=1,080	>48 h N=1,130	Overall N=4,066	p Value
LOS (d)					
Mean LOS (median)	4.96	6.40	12.66	7.48	**<.001***
Mean postsurgical LOS (median)	4.96	5.40	7.51	5.79	**<.001***
CES status					
Incomplete CES	1,089 (58.9)	687 (64.1)	690 (62.3)	2,466 (61.2)	**.013**
Complete CES	761 (41.4)	384 (35.9)	418 (37.7)	1,563 (38.8)	
Causes of CES					
Degenerative					
Herniated nucleus pulpous	1087 (58.6)	594 (55.0)	428 (37.9)	2109 (51,9)	**<.001**
Stenosis or spondylosis	242 (13.0)	155 (14.4)	220 (19.5)	617 (15.2)	**<.001**
Spondylolisthesis	13 (0.7)	13 (1.2)	9 (0.8)	35 (0.9)	.350
Traumatic	72 (3.9)	68 (6.3)	99 (2.4)	239 (5.9)	.343
Spinal malignancy	2 (0.1)	3 (0.3)	4 (0.4)	9 (0.2)	**<.001**
Epidural abscess and Pott disease	33 (1.8)	20 (1.9)	45 (4.2)	100 (2.5)	**<.001**
Others (or uncoded)	407 (21.9)	227 (21.0)	323 (28.6)	957 (23.5)	**<.001**

CAD, coronary artery disease; CES, cauda equine syndrome; CHF, congestive heart failure; COPD, chronic obstructive pulmonary diseases; CRF, chronic renal failure; DM, diabetes mellitus; IQR, interquartile range; LOS, length of stay; NIS, Nationwide Inpatient Sample; PVD, peripheral vascular disease; SD, standard deviation.

Values in boldface are statistically significant, determined at α≤0.05.

* Reported p values derived from the non-parametric Kruskal-Wallis test after graphic (histograms, Q-Q plots, stem-and-leaf plots) and numeric (Shapiro-Wilk test) assessments confirming a non-Gaussian distribution for exposure variables.

† Frequencies and proportions reported after excluding patients with missing values for gender (0.2%), race (10.9%), payer (0.4%), median income quartiles (2.2%), hospital bed size (0.8%), and teaching status (0.8%).

‡ Inflation adjusted values over the 10-year period to 2013 US$ amounts using the national consumer price index calculator.[11]

p<.001) as compared with those undergoing a surgical intervention within 24 hours (Table 3).

Regression model derivation

A multivariable log-binomial regression analysis was performed for the outcomes of unfavorable discharge, and prolonged postsurgical LOS (>75 percentile) for the overall cohort, followed by subgroup analyses for those with incomplete CES (without incontinence) and complete CES (with incontinence), and degenerative and traumatic etiologies. An additional model was constructed for inpatient mortality on the overall cohort of patients. OLS was employed to model hospital charges across all cohorts. In adjusted analyses, the

Table 2
Postoperative outcomes in patients registered in the NIS who underwent a surgical intervention for CES between 2005 and 2011

Complications	Time to intervention <24 h	24 to 48 h	>48 h	Overall (N=4,066)	p Value
Inpatient mortality†	≤10‖	≤10‖	22 (1.9)	35 (0.9)	**<.001**
Unfavorable discharge*,†	525 (28.4)	370 (34.5)	623 (56.2)	1,581 (37.7)	**<.001**
High-end hospital charges†,§	261 (14.6)	231 (22.1)	493 (44.3)	985 (25.0)	**<.001**
Prolonged postsurgical LOS (days)‡	292 (15.7)	189 (17.5)	334 (29.6)	815 (20.0)	**<.001**
Deep venous thrombosis	43 (2.3)	39 (3.6)	91 (8.1)	173 (4.3)	**<.001**
Pulmonary embolism	32 (1.7)	27 (2.5)	46 (4.1)	105 (2.6)	**<.001**
Acute renal failure	24 (1.3)	22 (2.0)	96 (8.5)	142 (3.5)	**<.001**
Wound complications	83 (4.5)	53 (4.9)	61 (5.4)	197 (4.8)	.517

CES, cauda equine syndrome; LOS, length of stay; NIS, Nationwide Inpatient Sample.

Values in boldface are statistically significant, determined at α≤0.05.

* Reported values exclude patients with inpatient mortality along with its missing values (0.2%).

† Reported values exclude patients with missing values for inpatient mortality (0.05%), unfavorable discharge (0.05%), and hospital charges (3.05%).

‡ Values depict frequencies (proportion) of patients with LOS above the third quartile (LOS>7 days).

§ Values depict frequencies (proportion) of patients with hospital charges above the third quartile (charges>US$107975) following inflation adjustments to 2015 dollar amounts.

‖ Output suppressed in concordance with Agency of Healthcare Research and Quality reporting guidelines for Healthcare Cost and Utilization Project data that prevent tabulation of data with values of ≤10.

Table 3
Patient characteristics across categories of timing to intervention in patients with incomplete and complete CES

Characteristics	Time to intervention			Overall (N=4,066)	p Value
	<24 h	24–48 h	>48 h		
Incomplete CES					
Mean age±SD (y)	46.54±16.08	49.24±16.80	58.64±17.60	50.72±17.48	**<.001**
Female gender, n (%)	440 (40.4)	294 (42.6)	286 (40.6)	1,020 (41.1)	.635
Charlson Comorbidity Index					
Mean (median)	2.83 (2)	3.03 (2)	3.94 (3)	3.20 (3)	**<.001**
Low (0–2)	595 (54.4)	358 (51.7)	248 (35.2)	1,201 (48.2)	**<.001**
Moderate or high (≥3)	498 (45.6)	335 (48.3)	457 (64.8)	1,290 (51.8)	
Inpatient mortality	≤10	≤10	15 (2.1)	25 (1.0)	**.001**
Unfavorable discharge	255 (23.4)	206 (30.0)	381 (55.2)	842 (34.1)	**<.001**
Hospital charges					
Mean	58,474	75,509	139,795	86,418	**<.001**
Median	38,718	49,174	97,822	52,321	**<.001**
Postsurgical LOS					
Mean (median) (d)	4.42 (3)	4.69 (3)	6.91 (5)	5.20 (4)	**<.001**
Prolonged postsurgical LOS	196 (17.9)	121 (17.5)	249 (35.3)	566 (22.7)	**<.001**
Complete CES					
Mean age±SD (y)	46.33±16.95	48.12±17.32	54.78±17.76	49.05±17.61	**<.001**
Female gender, n (%)	319 (41.9)	187 (48.3)	179 (42.1)	685 (43.5)	.090
Charlson Comorbidity Index					
Mean (median)	2.89 (3)	2.98 (2)	3.53 (3)	3.09 (3)	**<.001**
Low (0–2)	375 (49.1)	202 (52.2)	167 (39.3)	744 (47.2)	**<.001**
Moderate or high (≥3)	388 (50.9)	185 (47.8)	258 (60.7)	831 (52.8)	
Inpatient mortality	≤10	≤10	≤10	≤10	**.007**
Unfavorable discharge	270 (35.5)	164 (42.7)	242 (57.9)	676 (43.3)	**<.001**
Hospital charges					
Mean	66,290	96,033	134,882	92,648	**<.001**
Median	42,048	59,681	96123	56,858	**<.001**
Postsurgical LOS					
Mean (median) (d)	5.73 (4)	6.68 (4)	8.50 (6)	6.71 (4)	**<.001**
Prolonged postsurgical LOS	142 (18.6)	88 (22.7)	145 (34.1)	375 (23.8)	**<.001**

CES, cauda equine syndrome; LOS, length of stay; SD, standard deviation.
Bold faced values are statistically significant.

association of time to intervention for CES patients was explored for each of the primary outcomes.

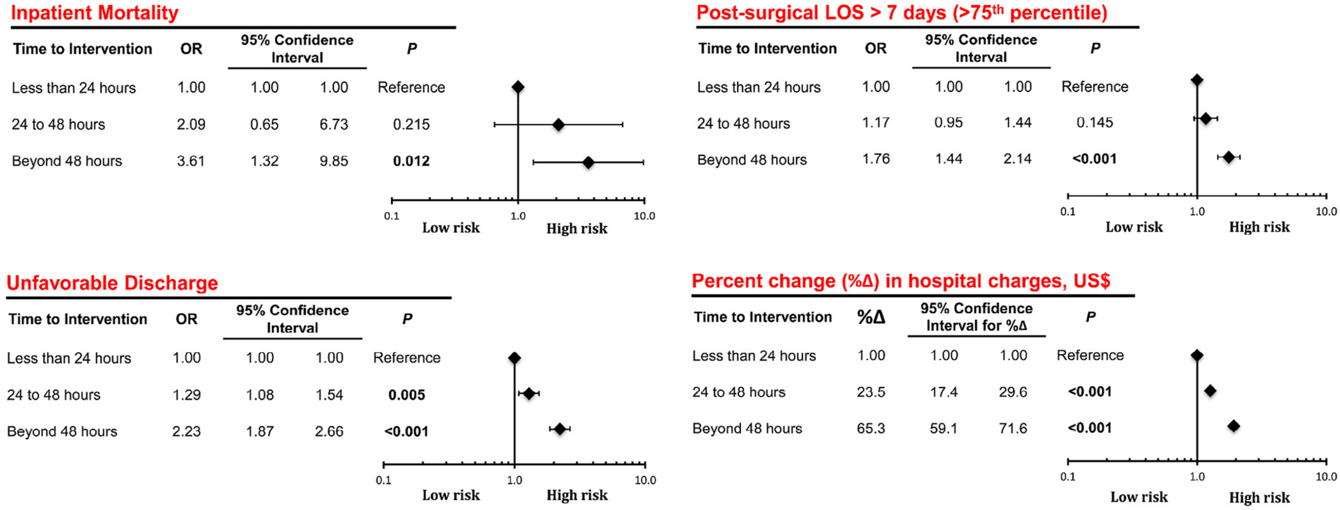
Overall, the timing to intervention had a significant impact on outcomes. Patients operated on beyond 48 hours from admission had a higher likelihood of inpatient mortality (OR: 3.61, 95% CI: 1.32–9.85, p=.012), unfavorable discharge (OR: 2.23, 95% CI: 1.87–2.66, p<.001), and prolonged postsurgical LOS (OR: 1.76, 95% CI: 1.44–2.14, p<.001) with reference to those operated on within 24 hours (Fig. 2). Also, patients operated on beyond 48 hours were noted to incur 65.3% higher hospital charges (OR: 1.92, 95% CI: 1.81–2.05, p<.001) as compared with those operated on within 24–48 hours. A similar trend was observed in patients with incomplete CES who were operated on day 2 or beyond since admission with higher odds for unfavorable discharge (OR: 2.51, 95% CI: 1.99–3.17, p<.001), prolonged postsurgical LOS (OR: 1.73, 95% CI: 1.35–2.20, p<.001), and incurred charges (OR: 1.94, 95% CI: 1.79–2.10, p<.001). Back-transformation of estimates for hospital charges revealed that patients with late intervention incurred 66.3% higher charges as compared with the early intervention group (Fig. 3).

Likewise, a similar trend was observed in patients with complete CES. For these patients, any delay in intervention beyond 24 hours was significantly associated with an increased likelihood of unfavorable discharge (24–48 hours: OR: 1.35, 95% CI: 1.02–1.77, p=.035; >48 hours: OR: 1.86, 95% CI: 1.41–2.45, p<.001), prolonged postsurgical LOS (24–48 hours: OR: 1.42, 95% CI: 1.04–1.95, p=.029; >48 hours: OR: 2.06, 95% CI: 1.53–2.77, p<.001), and hospital charges (24–48 hours: OR: 1.40, 95% CI: 1.27–1.55, p<.001; >48 hours: OR: 1.90, 95% CI: 1.72–2.10, p<.001). Moreover, we noted that the percent change in incurred charges were 33.6% and 64.1% higher in patients operated on within 24–48 hours and >48 hours, respectively, in comparison with patients who received early intervention (Fig. 4).

All log-binomial regression models demonstrated good discrimination with an area under the curve for each model across the medical interventional and operative cohort above 0.65.

Degenerative and traumatic etiologies

We extended our analysis to include a subgroup analysis of patients with CES with degenerative and traumatic etiologies (Table 4). We noted that patients with degenerative CES operated on beyond 48 hours were at higher odds for an unfavorable discharge (OR: 1.98; 95% CI: 1.56–2.50;



Inpatient Mortality

Time to Intervention	OR	95% Confidence Interval		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	2.09	0.65	6.73	0.215
Beyond 48 hours	3.61	1.32	9.85	**0.012**

Unfavorable Discharge

Time to Intervention	OR	95% Confidence Interval		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	1.29	1.08	1.54	**0.005**
Beyond 48 hours	2.23	1.87	2.66	**<0.001**

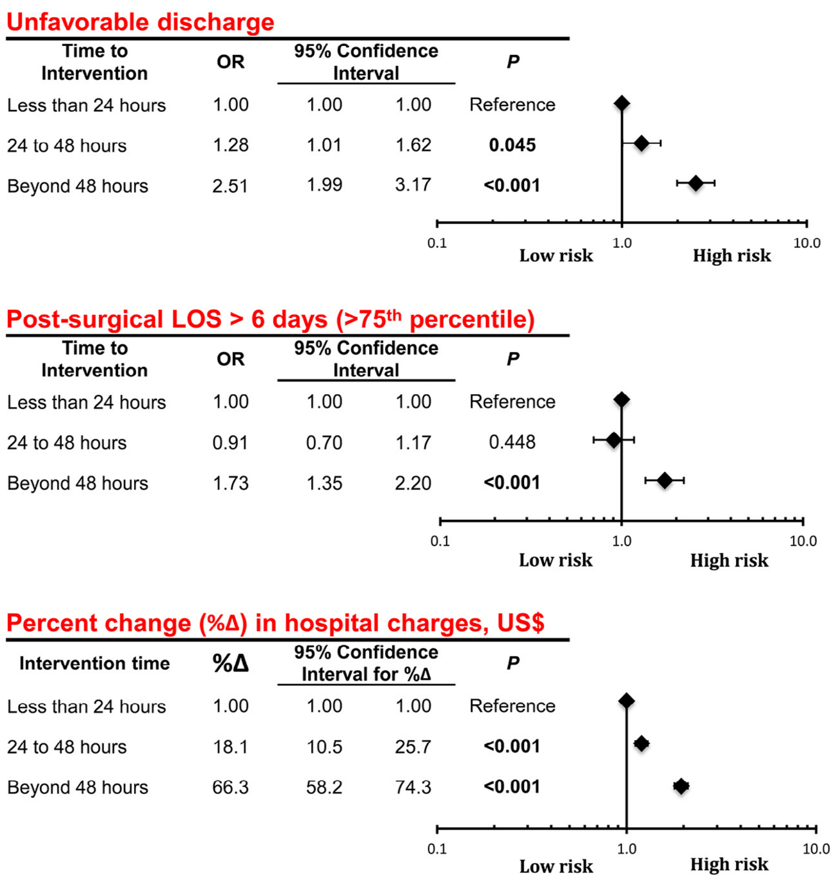
Post-surgical LOS > 7 days (>75th percentile)

Time to Intervention	OR	95% Confidence Interval		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	1.17	0.95	1.44	0.145
Beyond 48 hours	1.76	1.44	2.14	**<0.001**

Percent change (%Δ) in hospital charges, US$

Time to Intervention	%Δ	95% Confidence Interval for %Δ		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	23.5	17.4	29.6	**<0.001**
Beyond 48 hours	65.3	59.1	71.6	**<0.001**

Fig. 2. Multivariable log-binomial regression model demonstrating the association of inpatient mortality, unfavorable discharge, prolonged LOS, and high hospital charges, with extent of timing to intervention in all patients with cauda equina syndrome (incomplete+complete). The reference value is patients who received intervention within 24 hours of admission. The corresponding forest plots are displayed on the right. LOS, length of stay; OR, odds ratio.



Unfavorable discharge

Time to Intervention	OR	95% Confidence Interval		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	1.28	1.01	1.62	**0.045**
Beyond 48 hours	2.51	1.99	3.17	**<0.001**

Post-surgical LOS > 6 days (>75th percentile)

Time to Intervention	OR	95% Confidence Interval		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	0.91	0.70	1.17	0.448
Beyond 48 hours	1.73	1.35	2.20	**<0.001**

Percent change (%Δ) in hospital charges, US$

Intervention time	%Δ	95% Confidence Interval for %Δ		*P*
Less than 24 hours	1.00	1.00	1.00	Reference
24 to 48 hours	18.1	10.5	25.7	**<0.001**
Beyond 48 hours	66.3	58.2	74.3	**<0.001**

Fig. 3. Multivariable log-binomial regression model demonstrating the association of unfavorable discharge (Top panel), prolonged LOS (Middle panel), and high hospital charges (Lowest panel) with the extent of timing to intervention in patients with incomplete cauda equine syndrome. The reference value is patients who received intervention within 24 hours of admission. The corresponding forest plots are displayed on the right. LOS, length of stay; OR, odds ratio.

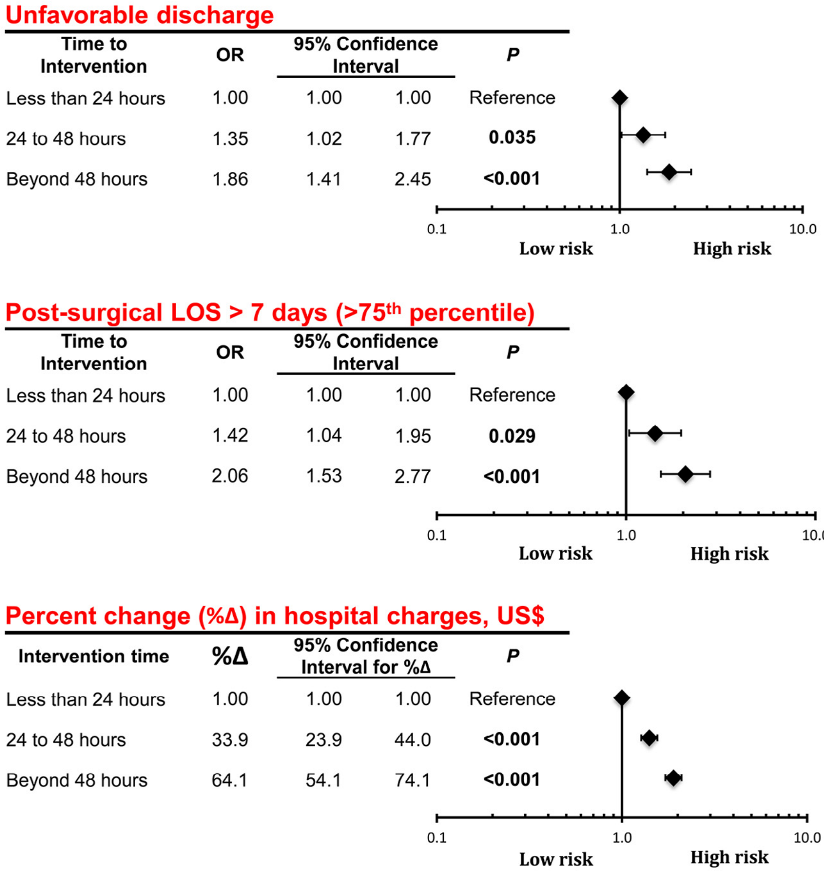


Fig. 4. Multivariable log-binomial regression model demonstrating the association of unfavorable discharge (Top panel), prolonged LOS (Middle panel), and high hospital charges (Lowest panel), with extent of timing to intervention in patients with complete cauda equine syndrome. The reference value is patients who received intervention within 24 hours of admission. The corresponding forest plots are displayed on the right. LOS, length of stay; OR, odds ratio.

p<.001) and prolonged hospital stay (OR: 1.37; 95% CI: 1.09–1.74; p=.008), and for incurring high charges (OR: 1.63; 95% CI: 1.52–1.76; p<.001) with reference to those operated on within 24 hours. The timing to intervention did not have any impact on mortality for these patients (Table 4).

In an adjusted subgroup analysis for patients with traumatic CES, we found timing to intervention to have no impact on discharge disposition to rehabilitation or hospital stay post intervention. However, these patients operated on beyond 48 hours were associated with higher odds for incurring high

Table 4
Association of timing to intervention on outcomes in patients with degenerative and traumatic CES

		Timing to intervention (h)	OR	95% Confidence interval		p Value
Causes	Outcomes	<24 h	1.0	1.0	1.00	Reference
Degenerative CES (n=2,761)	Inpatient mortality	24–48	0.37	0.04	3.81	.406
		>48	0.42	0.03	5.55	.513
	Unfavorable discharge	24–48	1.21	0.96	1.51	.109
		>48	1.98	1.56	2.50	**<.001**
	Prolonged postsurgical LOS (>5 days)	24–48	1.01	0.80	1.27	.936
		>48	1.37	1.09	1.74	**.008**
	Hospital charges	24–48	1.20	1.12	1.28	**<.001**
		>48	1.63	1.52	1.76	**<.001**
Traumatic CES (n=239)	Unfavorable discharge	24–48	1.33	0.59	3.00	.493
		>48	1.10	0.54	2.22	.793
	Prolonged postsurgical LOS (>12 days)	24–48	1.06	0.44	2.55	.900
		>48	1.20	0.56	2.61	.637
	Hospital charges	24–48	1.16	0.94	1.43	.162
		>48	1.39	1.15	1.68	**.001**

CES, cauda equine syndrome; LOS, length of stay; OR, odds ratio.
Bold faced values are statistically significant.

hospital charges (OR: 1.39, 95% CI: 1.15–1.68, p=.001) (Table 4).

Discussion

Emergence of 48-hour rule and its downfall

The urgency of surgical decompression has remained a contentious issue in the management of CES. Several studies have attempted to define timing to intervention following CES onset based on functional outcomes. A general consensus on "early intervention" for improved outcomes for these patients is well accepted; however, results from various studies quantifying a specific time range for improved outcomes has been conflicting. Most authors recommend a 48-hour period from symptom onset as the upper time limit for surgical decompression [1,2,33].

In 1959, Shephard suggested that early decompression may be important in preventing important neurologic sequelae [34]. In 2000, a meta-analysis by Ahn et al. [2] comprising 322 patients pooled from 42 eligible studies documented outcomes in patients with CES with respect to timing to intervention. The authors confirmed the significant advantage of treating patients within 48 hours in contrast to a post-48-hour period following CES onset. The merits of early intervention translated to a marked improvement in sensory and motor deficits and urinary and rectal functions. Interestingly, the authors noted no differences in outcomes in patients treated within 24 hours following CES onset in comparison to those treated between 24 and 48 hours of CES onset. This finding formed the basis of the controversial notion that delaying surgery up to 48 hours' time frame could possibly have a limited impact on outcomes, and set the tone for a 48-hour rule for surgical intervention in patients with CES. Despite the obvious merits of the study, inherent flaws relating to the study design including inclusion of traumatic CES, smaller sample size implying lower power to confer generalizability, and a lack of control group were major concerns to unanimously derive conclusions [35]. Moreover, the study was limited to a comprehensive overview of a subgroup analysis for patients with and without complete CES, and those relating to the common etiologies.

In a more recent and well-designed meta-analysis using stringent criteria with robust statistical techniques, DeLong et al. backed the recommendations of Ahn et al. supporting early intervention in CES. In a pooled analysis incorporating 16 observational studies, DeLong et al. demonstrated a significant improvement of urinary symptoms in patients being operated on within 24 hours in comparison to 72 hours. Strikingly, the authors noted no significant differences in outcomes across various subgroups, such as those operated on within <12–24 hours, 24–36 hours, and 36–48 hours [8]. Additionally DeLong et al. also emphasized the need to differentiate CES patients based on bladder involvement (retention vs. incontinence) while analyzing outcomes based upon timing to surgical intervention to plausibly mitigate potential bias. In a study reporting a retrospective cohort analysis of a single-surgeon experience in managing 40 patients with CES, Todd observed that bladder function was more likely to improve if surgical intervention was performed within 24 hours. The small sample size, lack of inferential statistics, and inherent selection bias because of the study design were obvious demerits of the study [3]. In a latest systematic review and meta-analysis, Chau et al. revisited the impact of timing to intervention on outcomes [1]. Chau et al. acknowledged the significant "discordance" in the literature relating to an emergency intervention favoring improved outcomes, but concluded that the lack of discrete evidence supporting the 48-hour dictum was a safe time point to delay surgery and that the degree of neurologic dysfunction (incomplete CES vs. complete CES) was likely to play a significant prognostic indicator. Chau et al. highlight that both early and delayed surgery may contribute to improved neurologic outcomes based upon individualized clinical condition, but recommend that an early intervention is more likely to benefit patients with acute deterioration because of compression of nerves. Nonetheless, the quantitative analysis based upon 200 patients pooled from five eligible studies concluded no statistical differences for the return of normal bladder function following a decompressive surgery (pooled OR: 1.16, 95% CI: 0.73–1.85, p=.52) regardless of early (within 48 hours) or delayed (post 48 hours) intervention. In a population-based cohort analysis using the data derived from California State Inpatient Databases over several years, Arrigo et al. determined the incidence of CES in surgically treated degenerative lumbar disc patients to be at 1.51%, translating to an average of 397 cases per year in California [12]. In comparison with other surgically treated patients with a degenerative lumbar disc, patients with CES were more prone to use higher health-care resources yet had worse outcomes in terms of LOS (4.12 days vs. 3.22 days, p<.001), hospital charges (US$42,083 vs. US$40,456), and discharge disposition (non-routine: 32.66% vs. 19.81%). In their analysis, the authors noted that approximately 90% of patients with CES were operated on within 48 hours of hospitalization. In the adjusted analysis, the group which were operated beyond the 48 hour window were associated with three times the odds for a non-routine discharge as compared to the former (OR: 3.08, 95% CI: 2.13–4.46, p<.001) [12].

The recent debate on early intervention for satisfactory outcomes in patients with CES emanated almost two decades earlier in animal models when Delamarter et al. [36] explored the relationship between the timing of surgery and the extent of neurologic recovery in 30 dogs with CES, divided in five groups of six, based on the timing of surgical L6–L7 laminectomy. After induction of 75% circumferential constriction of the cauda equina with a nylon cable, the groups were decompressed immediately or at 1-, 6-, and 24-hour or 1-week intervals. A temporal relationship between the duration of constriction and time to clinical improvement was observed. Functional neurologic outcomes were recovered within 2–5 days in the group undergoing immediate decompression following induction of CES, within 5–7 days in those undergoing intervention within 1 and 6 hours, whereas compression-induced dogs for 24 hours remained paraparetic for up to a week (5–7 days), with bladder and tail dysfunction persisting for 7–10 days and 4 weeks, respectively. Despite the initial improvement in the early-decompression groups, all dogs equally recovered and regained locomotion as assessed by their ability to walk and had improved bladder function at a 6-week mark following decompression. Further, no statistical differences were noted in the recovery of somatosensory-evoked potentials and histologic analysis of the cord anatomy. Based on their study findings, Delamarter et al. concluded that time to surgery in CES lacks any relationship to long-term neurologic recovery [36].

In our present analysis, we revisit the association of timing to surgical intervention in patients with CES on various surrogate outcomes such as discharge disposition, LOS, hospital charges, and mortality using robust statistical techniques, taking into account the nature and design of the database. Although the general consensus favored a 48-hour dictum, we hypothesized that patients with CES operated on even earlier, within 24 hours of symptom onset, was associated with improved outcomes. Using the NIS, the largest inpatient cohort in the United States, we assessed these outcomes in patients derived from diverse practice settings, geographic location, surgeon expertise, and facilities, enabling generalization of our derived estimates. Although our analysis was limited to surrogate inpatient outcomes only rather than the functional status, these defined outcomes intuitively defined the level of care received and indirectly predicted the functional outcomes. Regardless of the subtype of CES, either complete or incomplete, we noted decompression beyond 48 hours to be associated with poor inpatient outcomes, with increased likelihood for discharge to rehabilitation, prolonged hospital stay, and high charges as compared with those receiving early intervention (Figs. 2–4). Interestingly, patients with early intervention had a lower incidence of thromboembolic events such as the DVT (2.3% vs. 8.1%, p<.001), pulmonary embolism (1.7% vs. 4.1%, p<.001), and acute renal failure (1.3% vs. 8.5%, p<.001). These findings may lead us to treat CES like an acute spinal cord injury and may encourage us to test the treatment algorithms for complete versus incomplete spinal cord injury on CES in a more sophisticated study design.

Does timing of intervention matter in traumatic CES? Review of pathophysiology

The most common causes of CES include degenerative etiology followed by trauma. Our findings indicate that in patients with CES secondary to trauma, timing to intervention is associated with little or minimal benefit for inpatient outcomes. On the contrary, early intervention in patients with CES secondary to degenerative etiology is plausibly associated with lower resource use because of a lesser likelihood of unfavorable discharge (OR: 0.51, 95% CI: 0.40–0.64, p<.001), hospital stay (OR: 0.73, 95% CI: 0.57–0.64, p=.008), and incurred charges (OR: 0.61, 95% CI: 0.57–0.66, p<.001) as compared with those receiving delayed intervention. The pathophysiology of cauda equine syndrome (CES) is attributed to the duration of axonal viability following nerve root compression [36]. Prolonged compression induces secondary mechanisms of cell death. Restricted axoplasmic flow induces Wallerian degeneration in motor nerve roots distal to and sensory nerve roots proximal to the compression site. Additionally, hypoxic insult from arterial stenosis, local inflammation from endoneural vascular congestion, and disruption of remyelination may occur. The principle of progressive axonal decline secondary to compression has been translated into the surgical recommendation, encouraging prompt decompression of the compression site to mitigate the process of Wallerian degeneration. There have been suggestions that the sudden nature of trauma results in a higher degree of irreversible neuronal cell death as opposed to longstanding compressive etiology. These findings may explain the difference in outcomes (discharge dispositions) in patients (Traumatic vs. Degenerative) undergoing early intervention for CES in our study.

Could consensus ever be reached? Summary of results and implications in the medicolegal system

Following the evaluation of relevant literature entailing the impact of timing to intervention on outcomes, and comparing with our findings, a general consensus based upon evidence-based guidelines to standardize outcomes in managing CES is warranted. With variability in outcomes across different caveats of CES (complete vs. incomplete, degenerative vs. traumatic), more stringent guidelines for treating these patients may be effectively tailored upon individual status. Although findings from recent retrospective studies reflect that early intervention may not significantly improve urinary functions or motor recovery in patients with complete CES [1,5], our analysis demonstrate a clear overall benefit for both complete CES and incomplete CES as it relates to the inpatient outcomes that we investigated. A clear socioeconomic benefit with decreased hospital charges and hospital stay was noted in the early intervention group.

Reviewing the animal studies and pathophysiological features of CES, neurologic deterioration is constant and neuronal damage occurs cumulatively over time unlike a spike-plateau-spike phenomenon [36]. Results of our study or a previous meta-analysis encouraging early intervention may serve as a guideline for patient counseling in regard to predicting inpatient outcomes, albeit tailored upon patient-specific factors. Although rare, CES is considered as a spinal emergency, and medical-legal issues governing this pathological state are disproportionately high. Gardner et al. [7] reviewed the database for Medical Protection Society in the United Kingdom. A 5-year analysis revealed that the average payment per litigation amounted to £117,331, with the maximum recorded settlement being £584,000. Daniels et al. [6] reviewed the LexisNexis Academic Database, which offers information on US Supreme Court decisions from 1983 to 2010. Fifteen lawsuits were identified, and an intervention following a 48-hour time point since symptom onset was associated with an adverse legal decision against the treating surgeon. Injury severity was not necessarily correlated with getting sued. Of high interest was that, in 14 of the 15 cases, no digital rectal exam was documented. Although malpractice claims may start from adverse outcomes, the settlements are more dependent on the timing to intervention.

Limitations

Despite the obvious merits of using administrative databases for observational methods, limitations governing their use are well known [37] and are applicable to the present analysis as well. The database is inherently susceptible to reporting bias including coding errors resulting from under-reporting or missed reporting of events [38,39]. Although the NIS database represents 20% of US non-federal hospital discharges, the lack of longitudinal data, including follow-ups and outpatient and readmission data, limits analysis to short-term inpatient stay only. As a direct result, evaluation of improvement in the urinary symptoms for these patients post index admission is limited. Although the database provides the day of a specific intervention since admission (eg, within 24 hours of admission or later), this may not be universally extrapolated to the onset of symptoms. Further, the projected estimates in our study are subjected to residual confounding. Pertinent factors influencing outcomes and lacking in the NIS database include the neurologic status of the patient at the time of presentation (Glasgow Coma Scale), the mechanism of injury, the Injury Severity Score for traumatic CES, the time of onset of symptoms, electrophysiological data, and grades of functional assessment for bowel or bladder and sexual dysfunctions. Nevertheless, the sheer volume of patients from various geographic and clinical practice settings, variable provider volumes, and surgical expertise confer an objective observational assessment of outcomes in patients with CES and limit selection bias. Our study findings serve to provide additional supporting evidence on timing to intervention in these patients, warranting external validation and randomized clinical trials to test the associations derived from our analyses before consensus for a standardized approach relating to time to surgical decompression can be established.

Conclusions

Timing of intervention still remains critical in managing CES. It is more appropriate to categorically define CES (as suggested previously in the literature) as complete CES and incomplete CES to have a uniform system of reporting outcomes in literature. Regardless of the type of CES, complete or incomplete, our data suggest that a delay in intervention beyond 48 hours with reference to with 24 hours is associated with inferior inpatient outcomes with a higher likelihood for unfavorable discharge, LOS, and charges. Traumatic CES is less likely to improve during the inpatient stay in comparison to the degenerative etiology. Future studies including prospective trials are warranted to elucidate the impact of early intervention on outcomes in patients with CES.

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Supplementary material

Supplementary material related to this article can be found at http://dx.doi.org/10.1016/j.spinee.2017.04.023.

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