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Association Between Time-to-Rehabilitation and Outcomes Following Traumatic Spinal Cord Injury

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Abstract

Objective—To describe the relationships between time-to-rehabilitation (TTR) following spinal cord injury (SCI) and rehabilitation outcomes, as measured at discharge and 1-year post injury.

Design—Retrospective cohort study. TTR was defined as the number of days between injury and admission to inpatient rehabilitation. Instrumental variables regression was used to reduce confounding from unmeasured severity of illness/comorbidities. Models controlled for sociodemographic and injury characteristics, year of admission, Functional Independence Measure (FIM) motor score at admission, and rehabilitation length of stay.

Setting—United States facilities designated as SCI Model Systems (n=21).

Participants—Patients experiencing traumatic SCI between 2000 and 2014, who were 18 years or older, and who were admitted to a Model System within 24 hours of injury (n=3,937).

Interventions—Not applicable.

Main Outcome Measures—Rasch-transformed FIM motor score at discharge and 1-year post injury, discharge to a private residence, and the Craig Handicap Assessment and Reporting Technique (CHART) Physical Independence and Mobility scores at 1-year post injury.

Results—After accounting for health status, a 10% increase in TTR was associated with a 1.50 lower FIM motor score at discharge (95% CI, −2.43 to −0.58; P=0.001) and a 3.92 lower CHART Physical Independence score at 1-year post injury (95% CI, −7.66 to −0.19; P=0.04). Compared to the mean FIM motor score (37.5) and mean CHART Physical Independence score (74.7), these

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values represent relative declines of 4.0% and 5.3%, respectively. There was no association between TTR and discharge to a private residence, 1-year FIM motor score, or the CHART mobility score.

Conclusions—Earlier rehabilitation following traumatic SCI may improve patients' functional status at discharge.

Keywords

spinal cord injuries; rehabilitation; outcome assessment (health care); econometric models

Approximately 12,000 Americans experience traumatic spinal cord injury (SCI) each year,¹ the incidence of which has remained stable over the past decades.² During the same period, both acute care and rehabilitation lengths of stay (LOS) for SCI have fallen markedly.^{1, 3} However, one factor—the duration of time that patients with SCI spend in an acute care setting—still varies widely,⁴ and this variation may be related to underlying severity of illness and medical need.^{5, 6} This variation is important because delays in transfer to rehabilitation often occur when harnessing neuroplasticity is crucial for functional recovery.⁷ Over half of expected recovery occurs in the first 2 months post injury, with subsequent improvement plateauing after 3–6 months.⁸ Comparing similar patients, it is unclear whether additional time spent in acute care while forgoing rehabilitation is beneficial.

The benefits of early rehabilitation in illness recovery are beginning to be understood with respect to stroke care, critical care, and recovery from neuromotor deficits.^{9–14} Earlier rehabilitation may improve functional status for patients with SCI.^{15, 16} However, this evidence is over 10 years old, limited in scope by small samples in Italy and Japan, and may not generalize to the United States.¹⁷ Thus it remains unclear whether differences in the time-from-injury to rehabilitation affects patient outcomes in the U.S.

The objective of this study was to examine the relationship between time-to-rehabilitation (TTR) following SCI and rehabilitation outcomes at discharge and 1-year post injury. We hypothesized that a longer TTR interval would be negatively associated with outcomes.

METHODS

Data Source

Data were obtained from the Spinal Cord Injury Model Systems (SCIMS), a network of federally funded facilities that has collected data since 1973¹⁸ on the demographic and clinical characteristics for approximately 13% of all SCI cases in the United States.

Participants

Patients were included based on the following criteria: those experiencing traumatic SCI between 2000 and 2014 (N=10,506), who were at least 18 years of age at the time of injury (N=9,963), were admitted to a Model System facility within 24 hours of injury (N=4,063), and did not spend any days outside of a Model System on short-term discharges (N=3937). By including only patients entering a Model System facility within 24 hours of injury, we sought to reduce confounding by care provided in other healthcare systems and to establish a

similar baseline for all patients. The final study population consisted of 3,937 patients treated in 21 Model Systems representing 23 rehabilitation facilities. These patients were largely similar in terms of preinjury characteristics to the full sample of SCIMS patients collected between 2000 and 2014 (supplementary Table S1).

Measures

TTR, the main variable of interest, was measured as the number of days between the injury and admission to inpatient rehabilitation. Independent variables, measured at the time of injury, included: age, sex, race or ethnic group, marital status, education, job status, private residence, injury etiology and severity, and whether the injury was work-related. Injury severity was classified in a similar way to that of prior SCIMS studies¹⁹ as follows: C1-4 level injuries with American Spinal Injury Association (ASIA) Impairment Scale (AIS) ratings of A, B, or C; C5-8 level injuries with AIS A, B, or C ratings; T1-S3 level injuries with AIS A, B, or C ratings; and all injuries with AIS D ratings. A final category, unknown, was included because the injury severity information for 544 patients was not documented at rehabilitation admission. Additional variables included admission year, ventilator use, whether spinal surgery was performed, rehabilitation LOS, and the Functional Independence Measure (FIM)²⁰ motor score (Rasch-transformed²¹) on admission to inpatient rehabilitation.

Pre-specified outcome measures were selected based on prior research and the plausibility that they could be affected by TTR.^{15, 16} These measures included the FIM motor score at discharge (the primary outcome) and at 1-year post injury (both Rasch-transformed), a dichotomous measure of discharge to a private residence, and the Craig Handicap Assessment and Reporting Technique (CHART)²² Physical Independence and Mobility subscale scores at 1-year post injury. CHART scores on both the Physical Independence and Mobility dimensions range from 0 to 100, where 100 denotes the level of performance expected of individuals without disability.

Statistical Analysis

Determining to what extent TTR influences outcomes is confounded by severity of illness and comorbidities—i.e., more severely ill patients likely require longer acute care stays prior to rehabilitation. Thus, their total TTR will be longer and they are likely to have poorer functional status and other outcomes. Consequently, earlier rehabilitation could appear beneficial in standard regression analyses if patients' health status is not adequately accounted for. Therefore, our empirical approach differentiates between variations in the care received and variations in patients' severity of illness. In addition to standard regression methods, we used instrumental variables analysis to attenuate confounding by observed and unobserved confounders. Instrumental variables analysis is a commonly used econometric technique that requires identifying an observable variable (the "instrument") that is strongly correlated with TTR (instrument relevance) but is unrelated to severity of illness and has no direct effect on rehabilitation outcomes (instrument validity).²³

Because traumatic SCI represents an exogenous, unexpected, and acute change in health status, there is little reason to believe that the geographic location where the injury occurs is

related to patients' severity of illness, but geographic location is related to provider practice patterns concerning LOS. We exploit geographic variation as an instrumental variable, as it relates to the intensity of inpatient days utilized for end-of-life Medicare beneficiaries in each Model System's hospital referral region. (Hospital referral regions are local markets for tertiary health care that reflect where residents of that region receive the majority of their care.²⁴) Inpatient LOS at the end of life, as collected by *The Dartmouth Atlas of Health Care*,²⁵ reflects a region's tendency toward utilizing additional acute care resources (relevance) for patients who have similar health statuses because they are all at the end of life (validity).^{26–28} The intensity of end-of-life care in the Medicare population does not affect directly the rehabilitation outcomes of patients in our sample (validity).

Medicare patients treated in aggressive hospital referral regions incur more care transitions and a greater intensity of care at end of life—including more life-sustaining treatments—rather than palliative and supportive care.^{29, 30} This pattern of care is inconsistent with patients' preferences and reflects the local practice style of physicians and health system factors rather than patients' health statuses.³¹ We demonstrate graphically and using multivariate regression models that this regional propensity toward greater intensity of acute care in an end-of-life Medicare population is correlated with the TTR of patients with SCI in our sample because longer acute care stays lengthen the TTR interval. End-of-life treatment intensity measures have been used as instrumental variables in studies with similar research questions.^{32–34}

First, we estimated all models using ordinary least squares (OLS), which does not account for unobserved aspects of patient health status. Then, we estimated the same models using two-stage least squares instrumental variables regression, with the regional intensity of inpatient days utilized for end-of-life Medicare patients as the instrumental variable. Complete case analysis was used and all models controlled for sociodemographic and injury characteristics including injury severity, FIM motor score at admission to rehabilitation to control for baseline differences in functional status, year of admission to control for secular changes in treatment, and inpatient rehabilitation LOS to control for the independent effect of rehabilitation.³⁵ Standard errors were clustered to account for the fact that in any given year patients in the same Model System facility may be treated similarly.³⁶ Reasons for missing outcome data are provided in supplemental Table S2.

We conducted a sensitivity analysis to assess the robustness of the instrumental variables results by including an alternative instrumental variable based on the day of the week the patient was admitted. Admission day of the week is strongly associated with overall acute care LOS (relevance),^{37, 38} but is unrelated to patients' severity of illness and does not directly affect outcomes (validity).³⁹ For instance, patients admitted on Sundays and Mondays are more likely to be discharged on Friday compared with patients admitted Tuesday through Saturday, who stay in the hospital through the first weekend, thus incurring greater LOS.³⁹ We performed a test of over-identifying restrictions to assess whether the instruments were uncorrelated with the error term.⁴⁰ We also conducted a sensitivity analysis to examine whether including patients with short-term discharge days in the sample altered the results.

All analyses were conducted using Stata version 13.1; a P value of 0.05 or less designated statistical significance. This study was approved as a secondary analysis of de-identified data through expedited review by the Johns Hopkins Medicine Institutional Review Board.

RESULTS

Between 2000 and 2014, 3,937 patients meeting our inclusion criteria were treated in 23 Model System facilities. Table 1 presents patient and injury characteristics for the study population. The average age of patients at injury was 41.5 years; 79.2% were male, 62.8% were white, and 16.6% had C1-4 injuries with an American Spinal Injury Association Impairment Scale of A, B, or C. The standardized difference, an effect size measure that reflects practical significance, was used to compare patient characteristics in Model System facilities in regions with higher-versus-lower intensity of inpatient days among Medicare beneficiaries at the end of life. A standardized differences below 0.20 was considered to indicate a small effect size.⁴¹ Standardized differences in pre-injury patient characteristics were largely minimal when comparing Model System facilities in regions with higher-versus-lower intensity of inpatient days among Medicare beneficiaries at the end of life, indicating that the instrumental variable achieved a degree of balance between the groups. However, differences were observed in racial/ethnic group and education—with a higher percentage of white patients (70.3% vs. 55.4%) and patients with more than a high school education (25.8% vs. 13.6%) receiving care in regions with low-versus-high intensity of end-of-life LOS.

Figure 1 compares patient-level TTR in Model System facilities with low, intermediate, and high end-of-life intensity. The average TTR was 19.0 days (standard deviation, 23.0) and was 36% higher when comparing Model System facilities in regions with high-versus-low intensity of hospital days at the end-of-life (23 vs. 16). Region-level average inpatient days among end-of-life Medicare beneficiaries (the instrumental variable) were correlated strongly with patient-level TTR (first stage F statistic, 26.7; $P < 0.001$; supplemental Table S3) and exceeded recommended critical values.⁴² A 1-day increase in region-level average inpatient days among end-of-life Medicare beneficiaries was associated with a 9% increase (95% CI, 6% to 13%) in TTR among patients in our study population, demonstrating the relevance of the instrumental variable.

Table 2 compares the OLS and instrumental variables results for FIM motor score (the primary outcome), with full regression specifications. Table 3 compares the OLS and instrumental variables results for all outcomes. The OLS regressions, which do not account for unmeasured aspects of health status, demonstrated that longer TTR was associated with worse outcomes. Similarly, in the instrumental variables analyses that account for unmeasured health status, a 10% greater TTR was associated with a 1.50 lower FIM motor score at discharge (95% CI, -2.43 to -0.58 ; $P = 0.001$) and a 3.92 lower CHART Physical Independence score at 1-year post injury (95% CI, -7.66 to -0.19 ; $P = 0.04$). Compared to the mean FIM motor score at discharge (37.5) and mean CHART Physical Independence score (74.7), these differences represent relative declines of 4.0% and 5.3%, respectively, for an increase in TTR of approximately 2 days (using the mean TTR as a reference point).

There was no association between longer TTR and the likelihood of discharge to a private residence, 1-year FIM motor score, or the CHART mobility score.

The negative effects of greater TTR were robust in a sensitivity analysis that included an additional instrumental variable (admission day of week; supplemental Table S4). These models also demonstrated that the instruments were uncorrelated with the error terms of the models, supporting the validity of the instrumental variables strategy. Our results were unchanged when patients with short-term discharge days were included (supplemental Table S5).

DISCUSSION

Using a national sample of data on SCI patients spanning 15 years, we examined the relationship between the time-from-injury to inpatient rehabilitation and subsequent rehabilitation outcomes. After adjusting for patients' health status, a longer TTR was associated with a lower FIM motor score at discharge and a lower CHART Physical Independence score 1-year post injury. We found no association between longer TTR and the likelihood of discharge to a private residence, 1-year motor FIM score, or the CHART mobility score.

For the FIM motor score at discharge and the CHART Physical Independence score, the OLS and instrumental variables results are concordant in their directions of effect: longer TTR was negatively associated with outcomes. The OLS results showed negative effects of longer TTR for all of the outcomes studied but with smaller magnitudes than the instrumental variable results. Because SCI is a sudden and acute change in health status in generally younger individuals who have a limited number of serious pre-existing health issues, underlying health status may be relatively similar on average after controlling for demographic and injury variables. Horn and colleagues⁴³ demonstrated that patient and injury characteristics, which we included in these models, have adequate explanatory power for most SCI outcomes, with comorbidity measures adding little explanatory value. As such, the OLS models, which accounted for a comprehensive set of patient, injury, and care characteristics, may have sufficiently adjusted for health status. We nevertheless used instrumental variables analysis to address the possibility of unmeasured confounding between TTR and severity of illness. Both the OLS and instrumental variables results suggest modest benefits to earlier rehabilitation for patients with SCI. This study also highlights the opportunities offered by large population-based registries paired with econometric methods to study the effectiveness of rehabilitation.^{44, 45}

Prior studies have demonstrated benefits to earlier rehabilitation for individuals with SCI. Scivoletto and colleagues¹⁶ studied 150 patients in an Italian rehabilitation hospital and found that patients with longer TTR had lower Barthel Index scores and mobility scores at discharge. Sumida and colleagues¹⁵ studied 123 patients in 17 Japanese facilities and found that earlier rehabilitation was associated with improved ASIA motor scores and activities of daily living. We demonstrated similar results in a prior study that used propensity score weighting methods and publicly available data from the SCIREhab study,⁴⁶ which explicitly collected data on severity of illness (the primary source of unobserved confounding), albeit

in fewer Model Systems and years than the present study. In that study longer TTR was associated with a lower FIM motor score at discharge, in addition to lower FIM motor scores and CHART Physical Independence scores at 1-year post injury (supplementary Tables S6 and S7).⁴⁷ Viewed collectively, this prior research and the present study suggest benefits to earlier rehabilitation for individuals with traumatic SCI.

Improvements in functional recovery following SCI might be achieved if patients entered inpatient rehabilitation at the earliest, clinically appropriate opportunity. Achieving this aim may require improved communication between acute care providers and rehabilitation professionals, better education of acute care providers about the possible benefits of earlier rehabilitation,⁴⁸ and enhanced discharge planning across the care continuum.^{49, 50} New payment models currently being considered by policymakers, such as bundled payment—reimbursement for an entire episode of acute and post-acute care in a single payment—suggest future incentives for acute and post-acute care providers to integrate services and reduce delays to patients needing rehabilitation.⁵¹ At an organizational level, quality improvement interventions, which utilize standardized tools for changing the technical aspects of care delivery and the broader culture,⁵² are another plausible approach to improve care coordination. An alternate strategy would be to initiate rehabilitation interventions while patients are still in acute care. Early mobility protocols are used and evaluated for patients with neurologic injuries⁵³ and other critical illnesses.¹² Additional benefits of shorter TTR for patients with SCI include reductions in acute care LOS, which generates potential revenue opportunities for hospitals if the bed-days released by shorter lengths of stay are used for new admissions.⁵⁴

Study Limitations

This study has several limitations. First, because the SCIMS data are restricted to a small set of facilities, we confronted limited region-year variation in the instrumental variable. This restriction led to moderate imbalances between patients above versus below the median value of the instrumental variable on race and ethnic group (reflecting differences in the racial and ethnic distribution of the US) and education, and minor imbalances on other variables. Importantly, there was no evidence of positive selection—patient characteristics that would suggest worse health status were not more prevalent in higher-intensity Model System regions. Additionally, the sensitivity analyses that included alternative instrumental variables were consistent with our main results and supported the validity of the instrumental variable approach. Despite our efforts to address unobserved confounding, the results of this study should not be interpreted causally.

Second, it is unclear whether the results would generalize to patients with SCI treated in non-Model Systems facilities, though prior research has demonstrated that SCIMS data are broadly representative of the population of patients who experience traumatic SCI in the United States.⁵⁵ Nevertheless, because different facilities possess different capabilities for employing their resources to produce outcomes (in economic terms, they have different production functions), shortening of TTR in non-Model System facilities may not yield similar results to those observed in Model Systems facilities. Third, the SCIMS data do not report whether rehabilitation interventions were initiated during acute care. Unless the

likelihood of using rehabilitation during acute care is correlated with the instrumental variable, the results should not be biased by this limitation. Finally, our study does not ascertain the mechanisms underlying the negative effects of longer TTR. These negative effects may result from a failure to leverage neuroplasticity within a critical recovery window,⁷ or they could be the product of healthcare interventions of marginal or negative value during the acute care phase.⁵⁶ Future research could explore these alternative hypotheses.

CONCLUSIONS

We leveraged a large national sample of data on patients incurring traumatic SCIs to investigate the relationship between TTR and rehabilitation outcomes. The results complement and extend existing research that has demonstrated functional benefits to earlier rehabilitation or, conversely, negative effects of longer or delayed rehabilitation. Efforts to promote earlier rehabilitation following traumatic SCI, through quality improvement interventions or enhanced collaboration between acute and post-acute care providers, may improve patients' functional status at discharge.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

List of Abbreviations

AIS	ASIA Impairment Scale
ASIA	American Spinal Injury Association
CHART	Craig Handicap Assessment and Reporting Technique
CI	confidence interval
FIM	Functional Independence Measure
LOS	length of stay
OLS	ordinary least squares
SCI	spinal cord injury
SCIMS	Spinal Cord Injury Model Systems
TTR	time-to-rehabilitation

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Figure 1. Time-to-Rehabilitation Following Spinal Cord Injury

Regional intensity of hospital days at end-of-life is based on data reported in *The Dartmouth Atlas of Health Care* and is measured at the hospital referral region (HRR) level as the average number of inpatient days among Medicare beneficiaries in their terminal hospitalizations. “Low” refers to HRRs in the first tercile of regional end-of-life hospital days (median, 1.4 days; range, 0.9 to 1.6), “intermediate” refers to HRRs in the second tercile (median, 1.9 days; range, 1.6 to 2.4), and “high” refers to HRRs in the third tercile (median, 3.0 days; range, 2.4 to 7.0).

Table 1**Patient and Injury Characteristics**

Variable [†]	Full Sample (N = 3937)	Regional Intensity of Hospital Days at End-of-Life [*]		
		Below Median (N = 1968)	Above Median (N = 1969)	Standardized Difference [‡]
Age at injury in years, mean (SD)	41.5 (17.5)	42.8 (17.7)	40.2 (17.2)	0.15
Male, No. (%)	3119 (79.2)	1541 (78.3)	1578 (80.1)	−0.05
Race or ethnic group, No. (%)				
White	2473 (62.8)	1383 (70.3)	1090 (55.4)	0.31
Black	1013 (25.7)	332 (16.9)	681 (34.6)	−0.41
Hispanic	344 (8.7)	172 (8.7)	172 (8.7)	0.00
Other	107 (2.7)	81 (4.1)	26 (1.3)	0.19
Married, No. (%)	1411 (35.8)	736 (37.4)	675 (34.3)	0.07
Education at injury, No. (%)				
Less than high school	793 (20.1)	314 (16.0)	479 (24.3)	−0.21
High school	2368 (60.1)	1146 (58.2)	1222 (62.1)	−0.08
More than high school	776 (19.7)	508 (25.8)	268 (13.6)	0.32
Job status at injury, No. (%)				
Working	2377 (60.4)	1190 (60.5)	1187 (60.3)	0.00
Student	222 (5.6)	106 (5.4)	116 (5.9)	−0.02
Retired	451 (11.5)	251 (12.8)	200 (10.2)	0.09
Unemployed/other	887 (22.5)	421 (21.4)	466 (23.7)	−0.05
Private residence at injury, No. (%)	3864 (98.1)	1932 (98.2)	1932 (98.1)	0.00
Injury etiology, No. (%)				
Vehicular	1601 (40.7)	771 (39.2)	830 (42.2)	−0.06
Violence	626 (15.9)	239 (12.1)	387 (19.7)	−0.20
Sports	246 (6.2)	157 (8.0)	89 (4.5)	0.13
Falls	1235 (31.4)	656 (33.3)	579 (29.4)	0.08
Other	229 (5.8)	145 (7.4)	84 (4.3)	0.13
Injury severity at rehabilitation admission, No. (%)				
C1–4, AIS grades ABC	653 (16.6)	389 (19.8)	264 (13.4)	0.18
C5–8, AIS grades ABC	539 (13.7)	228 (11.6)	311 (15.8)	−0.12
T1–S3, AIS grades ABC	1235 (31.4)	588 (29.9)	647 (32.9)	−0.06
AIS All D	966 (24.5)	554 (28.2)	412 (20.9)	0.17
Unknown	544 (13.8)	209 (10.6)	335 (17.0)	−0.19
Injury work-relatedness, No. (%)	356 (9.0)	181 (9.2)	175 (8.9)	0.01
FIM Motor Score, rehabilitation admission [§] , mean (SD)	19.3 (12.3)	19.0 (12.5)	19.6 (12.1)	−0.05

Abbreviations: AIS, American Spinal Injury Association Impairment Scale; FIM, Functional Independence Measure.

^{*} Regional intensity of hospital days at end-of-life is based on data reported in *The Dartmouth Atlas of Health Care* and is measured at the hospital referral region (HRR) level as the average number of inpatient days among Medicare beneficiaries in their terminal hospitalizations.

[†] Other variables included in our regression models (ventilator use, spinal surgery, and rehabilitation length of stay) are not presented in Table 1 because these measures may be related to provide practice patterns of regional intensity of utilization and are not expected to be exogenous characteristics of the patients. In the sample, 387 (9.8%) patient had ventilator use, 2984 (75.8%) had spinal surgery performed, and rehabilitation length of stay averaged 49.6 days (SD, 45.8 days). Admission year is also not included in Table 1 for brevity, but 1,946 patients (49.4%) were admitted in 2007 or later.

[‡] Calculated with respect to above the median. The standardized difference is an effect size measure that reflects practical significance; a standardized difference below 0.20 was considered to indicate a small effect.

[§] FIM Motor score expressed as equal-interval measure using Rasch-transformation.

Table 2

Regression Results for Change in Rasch-transformed FIM Motor Score at Discharge Associated with a 10% Increase in Time-to-Rehabilitation

	Ordinary Least Squares Coefficient (95% CI)	Instrumental Variables Coefficient (95% CI)
TTR *	-0.22 (-0.26 to -0.18) ***	-1.50 (-2.43 to -0.58) **
Age at injury	-0.057 (-0.082 to -0.032) ***	-0.074 (-0.11 to -0.035) ***
Male (vs. female)	1.23 (0.59 to 1.87) ***	1.99 (0.79 to 3.20) **
Race or ethnic group		
White	Reference	Reference
Black	-1.85 (-2.77 to -0.93) ***	-2.25 (-3.74 to -0.77) **
Hispanic	0.84 (-0.39 to 2.07)	3.16 (0.87 to 5.45) **
Other	0.83 (-0.93 to 2.58)	2.19 (-0.65 to 5.03)
Married (vs. not married)	-0.44 (-1.05 to 0.17)	-0.47 (-1.49 to 0.56)
Education at injury		
Less than high school	Reference	Reference
High school	1.27 (0.51 to 2.03) **	0.84 (-0.35 to 2.04)
More than high school	1.37 (0.46 to 2.29) **	-0.55 (-2.64 to 1.54)
Job status at injury		
Working	Reference	Reference
Student	-0.64 (-1.86 to 0.59)	-3.36 (-6.03 to -0.68) *
Retired	-1.72 (-2.79 to -0.64) **	-1.37 (-3.02 to 0.28)
Other	-1.24 (-1.96 to -0.51) ***	-0.20 (-1.54 to 1.15)
Private residence at injury (vs. other)	-1.04 (-3.86 to 1.79)	-1.83 (-6.00 to 2.34)
Spinal surgery performed (vs. not)	1.26 (-0.14 to 2.66)	1.66 (0.08 to 3.24) *
Mechanical ventilation (vs. not)	-3.48 (-4.83 to -2.13) ***	4.28 (-1.36 to 9.92)
Injury etiology		
Vehicular	Reference	Reference
Violence	0.28 (-0.88 to 1.43)	0.54 (-1.31 to 2.39)
Sports	0.87 (-0.39 to 2.14)	-2.81 (-6.02 to 0.39)
Falls	-0.48 (-1.19 to 0.24)	-2.71 (-4.70 to -0.71) **
Other	-1.37 (-2.68 to -0.061) *	-2.64 (-4.95 to -0.33) *
Injury severity at rehabilitation admission		
C1-4, AIS grades ABC	Reference	Reference
C5-8, AIS grades ABC	4.37 (3.16 to 5.57) ***	4.72 (3.13 to 6.31) ***
T1-S3, AIS grades ABC	5.87 (4.50 to 7.24) ***	4.93 (3.12 to 6.75) ***
AIS All D	10.5 (9.14 to 11.8) ***	6.32 (2.84 to 9.81) ***
Unknown	6.27 (4.68 to 7.87) ***	5.94 (3.80 to 8.08) ***
Injury work related (vs. not work related)	0.94 (-0.047 to 1.92)	0.63 (-0.98 to 2.24)

	Ordinary Least Squares Coefficient (95% CI)	Instrumental Variables Coefficient (95% CI)
Admission year	0.060 (−0.070 to 0.19)	−0.069 (−0.27 to 0.13)
FIM Motor Score, rehabilitation admission [†]	0.49 (0.46 to 0.53) ***	0.48 (0.42 to 0.53) ***
Rehabilitation LOS	0.017 (0.0086 to 0.026) ***	0.041 (0.019 to 0.063) ***

Abbreviations: FIM, Functional Independence Measure; TTR, time-to-rehabilitation; AIS, American Spinal Injury Association Impairment Scale; LOS, length of stay.

* Coefficient is interpreted as the effect of a 10% increase in TTR, estimated from regressions using ordinary least squares or two-stage least squares instrumental variables estimation, with year-specific end-of-life hospital days for end-of-life Medicare beneficiaries in the patient's hospital referral region (HRR) as the instrumental variable. Standard errors were clustered to account for the fact that, in a given year, patients in the same Model System facilities are treated similarly.

[†] FIM Motor score expressed as equal-interval measure using Rasch-transformation.

Significance stars as follows:

* for p<0.05,

** for p<0.01, and

*** for p<0.001.

Table 3

Mean Values and Changes in Outcome Measures Associated with a 10% Increase in Time-to-Rehabilitation*

Outcome Measure	Mean Value	Ordinary Least Squares		Instrumental Variables	
		Change with 10% Increase in TTR (95% CI)	P Value	Change with 10% Increase in TTR (95% CI)	P Value
Discharge					
FIM Motor Score [†]	37.5	-0.22 (-0.26 to -0.18)	<0.001	-1.50 (-2.43 to -0.58)	0.001
Private residence (%) [‡]	83.4	-0.24 (-0.38 to -0.10)	0.001	1.69 (-0.27 to 3.66)	0.091
1-Year Post Injury					
FIM Motor Score [†]	52.8	-0.42 (-0.52 to -0.31)	<0.001	-0.54 (-2.05 to 0.97)	0.483
CHART Physical Independence	74.7	-0.42 (-0.58 to -0.25)	<0.001	-3.92 (-7.66 to -0.19)	0.040
CHART Mobility	73.8	-0.40 (-0.53 to -0.27)	<0.001	0.26 (-1.77 to 2.29)	0.802

Abbreviations: TTR, time-to-rehabilitation; FIM, Functional Independence Measure; CHART, Craig Handicap Assessment and Reporting Technique.

*The effect of a 10% increase in TTR was estimated from regressions using ordinary least squares or two-stage least squares instrumental variables estimation, with year-specific end-of-life hospital days for end-of-life Medicare beneficiaries in the patient's hospital referral region (HRR) as the instrumental variable. Regressions include covariates age at injury, sex, race or ethnicity, education, marital status, job status, private residence at injury, whether spinal surgery was performed and mechanical ventilation was used, traumatic etiology, neurologic category/injury severity (based on the American Spinal Injury Association Impairment Scale), whether the injury was work-related, admission year, Rasch-transformed FIM motor score on admission to inpatient rehabilitation, and length of stay in inpatient rehabilitation. Standard errors were clustered to account for the fact that, in a given year, patients in the same Model System facilities are treated similarly.

[†]FIM Motor scores expressed as equal-interval measures using Rasch-transformation.

[‡]Expressed as the percentage point change in the probability of being discharged to a private residence.