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ORIGINAL RESEARCH

Association Between Delayed Discharge From Acute Care and Rehabilitation Outcomes and Length of Stay: A Retrospective Cohort Study

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Abstract

Objective: To examine the association between discharge delays from acute to rehabilitation care because of capacity strain in the rehabilitation units, patient length of stay (LOS), and functional outcomes in rehabilitation.

Design: Retrospective cohort study using an instrumental variable to remove potential biases because of unobserved patient characteristics.

Setting: Two campuses of a hospital network providing inpatient acute and rehabilitation care.

Participants: Patients admitted to and discharged from acute care categories of Medicine and Neurology/Musculoskeletal (Neuro/MSK) and subsequently admitted to and discharged from inpatient rehabilitation between 2013 and 2019 (N=10486).

Interventions: None.

Main Outcome Measures: Rehabilitation LOS, FIM scores at admission and discharge, and rehabilitation efficiency defined as FIM score improvement per day of rehabilitation.

Results: The final cohort contained 3690 records for Medicine and 1733 for Neuro/MSK categories. For Medicine, 1 additional day of delayed discharge was associated with an average 5.1% (95% confidence interval [CI], 3%-7.3%) increase in rehabilitation LOS and 0.08 (95% CI, 0.03-0.13) reduction in rehabilitation efficiency. For Neuro/MSK, 1 additional day of delayed discharge was associated with an average 11.6% (95% CI, 2.8%-20.4%) increase in rehabilitation LOS and 0.08 (95% CI, −0.07 to 0.23) reduction in rehabilitation efficiency.

Conclusions: Delayed discharge from acute care to rehabilitation because of capacity strain in rehabilitation had a strong association with prolonged LOS in rehabilitation. An important policy implication of this “cascading” effect of delays is that reducing capacity strain in rehabilitation could be highly effective in reducing discharge delays from acute care and improving rehabilitation efficiency.

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Delays in discharge from acute care are prevalent in North American hospitals and those around the world.[1-5] These delays can be particularly long for patients requiring postacute care such as rehabilitation. Delayed discharges are costly for the health system because the delayed patients keep occupying acute care beds, possibly blocking new admissions and leading to hospital overcrowding.[2] In Canada, once acute care patients are determined to be clinically stable and no longer in need of the intensity of resources or services provided in acute care, their status is changed to alternative level of care (ALC)[6] until they are discharged to an appropriate care setting or reverts back to acute status. The age-adjusted average total acute length of stay (LOS) in Canada (except Quebec) has been relatively stable at around 7 days in recent years.[7] In 2020-2021, a total of 5.4% of hospital stays had

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ALC days, and 16.9% of patient days, or more than 2.7 million days, were in ALC.[7]

For patients requiring rehabilitation after their acute care, the transition can sometimes be delayed because of capacity-related constraints in the rehabilitation facility (eg, lack of available beds, care providers, and/or staff to coordinate transitions). We refer to such delays as capacity-driven delays. With a limited number of beds and staff and an increasing demand because of the aging population, rehabilitation facilities often operate at or close to full occupancy.

In addition to interrupting patient flow, delays in admission to rehabilitation care could adversely affect outcomes.[8-12] Although patients may receive lower-intensity rehabilitation in acute care, the goal is often to prevent further deterioration of the patients' conditions before they are admitted to rehabilitation care. The association between early initiation of rehabilitation activities in an inpatient rehabilitation facility and shorter LOS has been previously reported in the literature, for example, for stroke,[13,14] severe trauma,[15] and elective hip and knee arthroplasty.[9] In addition, several studies have reported an association between early admission to rehabilitation care and improved functional outcomes.[8-12] In these studies, delay typically includes the acute LOS, for example, defined as the time between the event of stroke or trauma and admission to rehabilitation. This does not single out the effect of capacity-driven delays incurred after completion of acute care. The effect of transfer delays, as measured by the number of ALC days, on rehabilitation LOS and functional status at discharge is investigated[15] but only focusing on patients with severe trauma.

We examined the association between capacity-driven delays, rehabilitation LOS, and functional outcomes for acute care categories of Medicine and Neurology/Musculoskeletal (Neuro/MSK) using data from 2 sites of a large hospital network. Our goal was to quantify and gain insights on the hospital-wide benefits of reducing capacity strain in rehabilitation.

Methods

Setting

Our study involved 2 sites of a large hospital network providing both acute and inpatient high-tolerance short-duration (HTSD) rehabilitation care. One site provided HTSD rehabilitation in a single facility with 55 beds, whereas the other provided HTSD rehabilitation in 4 facilities with a total capacity of 137 beds.

List of abbreviations:

ALC	**alternative level of care**
CI	**confidence interval**
HTSD	**high-tolerance short-duration**
IV	**instrumental variable**
LOS	**length of stay**
Neuro/MSK	**Neurology/Musculoskeletal**
OLS	**ordinary least squares**
RIW	**resource intensity weight**

Defining delays

Figure 1 illustrates the process of admitting a patient from acute to rehabilitation care at our institution.

The number of days spent with ALC status (ALC LOS) measures the total delay in discharge from acute care and admission to rehabilitation care. We further distinguish between 2 types of delays. Capacity-driven delays are those that are affected by capacity strain in rehabilitation and can be reduced by increasing bed and/or other resource capacity. Examples include delays because of unavailability of rehabilitation beds or delays in reviewing rehabilitation applications because of unavailability of staff. Noncapacity-driven delays, on the other hand, cannot be eliminated by increasing capacity and arise from necessary operations in the transition. Examples include the time to plan rehabilitation activities or the time spent physically transporting the patient.

Study design and data sources

We conducted a retrospective cohort study using hospitalization records for patients who were admitted to acute care after September 28, 2013, and subsequently discharged from inpatient HTSD rehabilitation before September 30, 2019. The data included patient characteristics as well as clinical and operational information. The data were extracted from the National Rehabilitation Reporting System, the Discharge Abstract Database of the Canadian Institute for Health Information,[16] and the hospitals' electronic health records. The details of specific variables used in our study are described in appendix 1, supplemental table S1. We followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline for cohort studies. Our study was exempted from review for human participant research by the Research Ethics Board of our institution.

Patient cohort

We limited our study to the 2 largest acute care categories: Medicine and Neuro/MSK. We used data for all patient categories to calculate the daily occupancy level of the rehabilitation units for the study period. We then restricted our analysis to January 1, 2015, to January 1, 2019, to ensure accurate calculation of occupancy levels (see appendix 2 for details). To reduce the estimation bias because of outliers, we excluded patient records with acute LOS smaller than the first percentile (3 days) and larger than the 97.5 percentile (56 days) as well as patient records with Acute ALC LOS larger than the 97.5 percentile (16 days). In our models, we controlled for rehabilitation categories and acute subcategories. We excluded rehabilitation categories and acute subcategories with less than 50 records.

Outcomes and covariates

The exposure variable was delay in care transition from acute to rehabilitation, measured by ALC LOS in acute care. In our analysis, we controlled for age, sex, comorbidity level, resource intensity weight (RIW), intervention (therapeutic or diagnostic), rehabilitation category, and site. Comorbidity levels are mutually exclusive levels (between 0 and 4) assigned based on the cumulative percentage increase in patient cost associated with certain comorbidity codes.[16] RIW measures the total use of hospital resources compared with typical acute patients and depends on

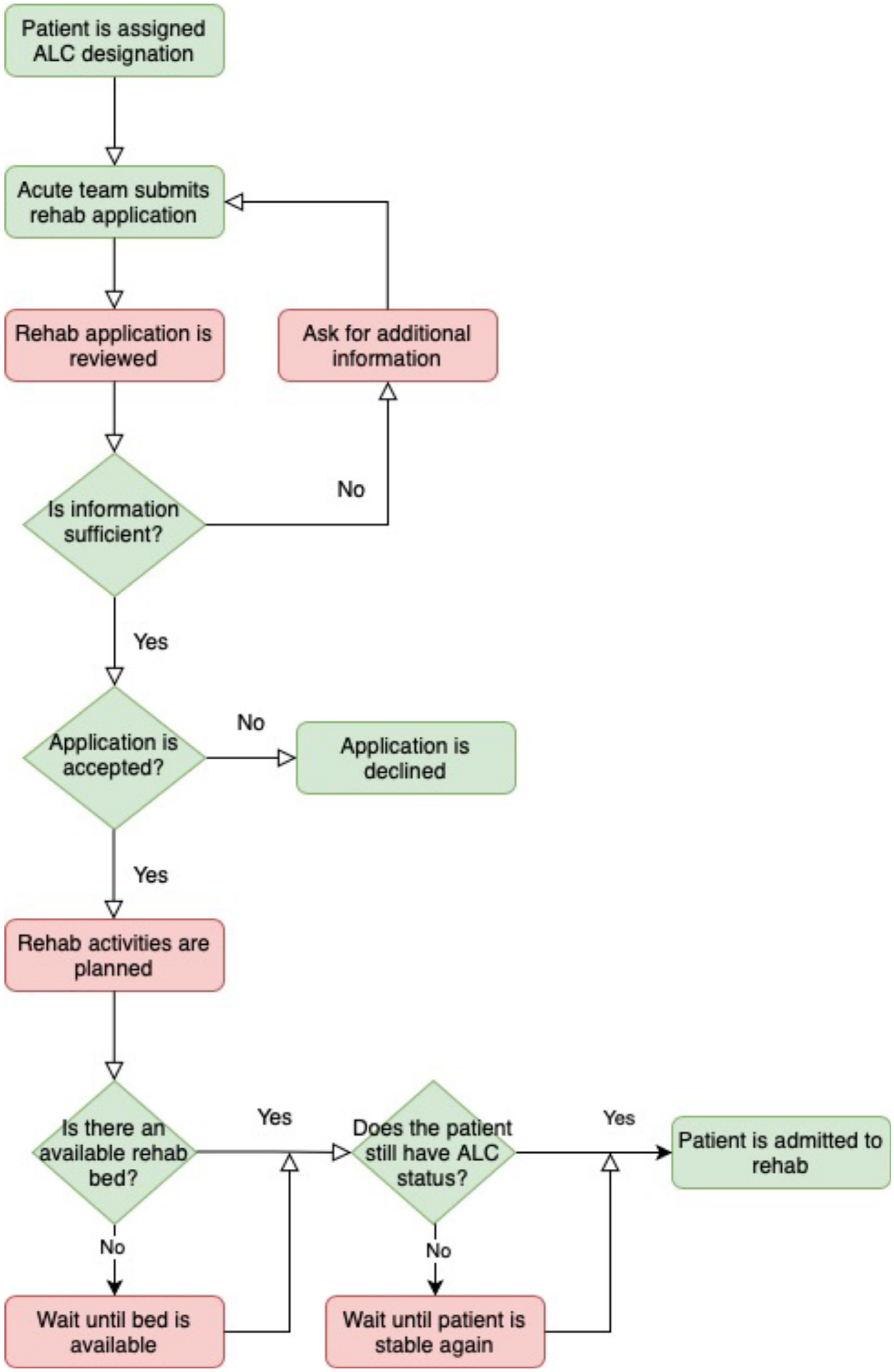

Fig 1 Summary of the steps involved in the rehabilitation admission process starting from the assignment of ALC status to admission. Steps highlighted in red indicate the possibility of incurring delays.

factors including age, comorbidities, and interventions.[16] As such, it can be viewed as a proxy for disease severity.

We considered 5 outcomes: (1) log rehabilitation active LOS is the natural logarithm of the number of days a patient received active rehabilitation care, that is, excluding days spent in rehabilitation because of delay in discharge; (2) FIM score at admission to rehabilitation; (3) FIM score at discharge from rehabilitation; (4) FIM score gain; and (5) rehabilitation efficiency. FIM is a standard measure between 18 and 126 for evaluating the functional capabilities of rehabilitation patients.[17] We took the logarithm of rehabilitation LOS because it had a long tail, that is, it took very large values for a small portion of patients. FIM score gain is defined as *FIM score at discharge from rehabilitation minus FIM score at admission to rehabilitation* and measures the improvement in functional capability of patients. Rehabilitation efficiency is calculated using *FIM score gain divided by rehabilitation active LOS* and measures the improvement in functional capability per day of rehabilitation.

Statistical analysis

To accurately measure the effect of capacity-driven delays on rehabilitation outcomes, one would ideally conduct a randomized experiment where patients are randomly assigned to experience different delays. Because such an experiment was infeasible, we instead conducted an observational study. Observational data can, however, lead to biased estimates because of unobserved patient characteristics that are correlated with both acute ALC LOS and rehabilitation outcomes. In addition, our single measurement of discharge delay (ALC LOS) may include both capacity-driven and noncapacity-driven delays.

To tackle these challenges, we used the instrumental variable (IV) method.[18,19] A proper instrument is one that appropriately mimics a randomized experiment. It should be correlated with the exposure variable—capacity-driven delays. Moreover, it should not affect the outcome variables except through its effect on capacity-driven delays, that is, it should be uncorrelated with unobserved patient characteristics. The IV approach has been used, for example, to examine the effect of early rehabilitation on in-hospital mortality for patients with aspiration pneumonia.[20]

We used rehabilitation occupancy at the time when the patient's status was changed to ALC as the IV. Occupancy is defined as the ratio of the number of patients in rehabilitation or waiting to be admitted to total rehabilitation bed capacity. Because the rehabilitation LOS was relatively long (on average 21.1 days), rehabilitation occupancy, which varies on a daily basis, at the time of receiving ALC status is unlikely to affect the rehabilitation outcomes other than through its effect on delays. In addition, rehabilitation occupancy only affects the capacity-driven delays and is unlikely to have an effect on noncapacity-driven delays. Therefore, it allows us to single out the effect of capacity-driven delays.

We examined the validity of the instrument using the Wald test[18] and by inspecting its correlation with ALC LOS. We used the 2-stage least squares method to estimate the models with the IV. We compared the estimates using 2-stage least squares method with those obtained using ordinary least squares (OLS), that is, without the IV.

To examine the robustness of our results, we considered 5 different model specifications. In Model 1 (base model) we controlled for age, sex, comorbidity level, intervention, and rehabilitation category. In Model 2, we also controlled for the site where the patient received care in addition to the controls in the base model. Model 3 was similar to Model 1, except that we controlled for RIW instead of comorbidity level. In Model 4, we controlled for acute subcategory in addition to the controls in the base model. In Model 5, we controlled for acute diagnosis in addition to the controls in the base model. We pooled diagnoses with <100 observations in 1 category. Finally, we conducted stratified analysis of Model 1 for the top diagnosis of each category.

Results

Cohort characteristics

Figure 2 summarizes our patient cohort selection. The final cohort for estimation contained 5423 hospitalization records, with 3690 belonging to the Medicine category and 1733 to Neuro/MSK.

Table 1 provides summary statistics for Medicine and Neuro/MSK categories. The 2 categories combined comprised 77.3% of the total acute care patients requiring rehabilitation during the study period.

Among the Medicine patients, 48% were male, the median age was 81 years, 49% had comorbidity level 2 or above, and 45%

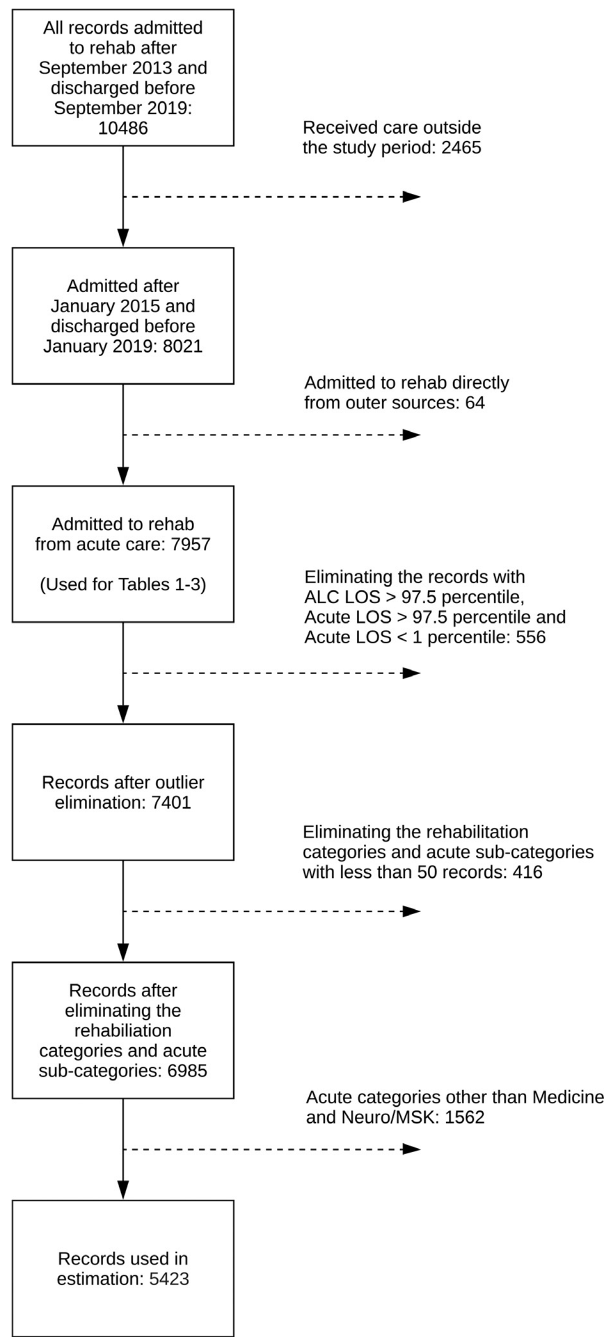

Fig 2 Selection of patient cohort.

Table 1 Patient characteristics and acute and rehabilitation information for Medicine and Neuro/MSK patients

Category		Medicine			Neuro/MSK		
Characteristic		Non-ALC	ALC	Total	Non-ALC	ALC	Total
Observations (n)		2352	1904	4256	1639	232	1871
Age (d), median (IQR)		81.0 (71.0-87.0)	81.0 (71.0-88.0)	81.0 (71.0-88.0)	76.0 (67.0-84.0)	73.0 (62.7-82.0)	76.0 (67.0-84.0)
Sex (% male)		47%	49%	48%	63%	60%	63%
Comorbidity (%)	No comorbidity	36	29	33	67	63	67
	Level 1	18	18	18	16	13	15
	Level 2	20	20	20	10	10	10
	Level 3	17	20	18	5	10	6
	Level 4	9	13	11	2	4	2
Acute characteristics							
RIW (d), median (IQR)		1.3 (0.9-2.1)	1.6 (1.0-2.8)	1.4 (0.9-2.4)	1.9 (1.5-2.7)	2.6 (1.7-4.0)	1.9 (1.5-2.8)
Acute active LOS (d), median (IQR)		8.0 (5.0-13.0)	8.0 (5.0-13.0)	8.0 (5.0-13.0)	8.0 (6.0-12.0)	8.0 (5.0-14.0)	8.0 (6.0-12.0)
Rehabilitation characteristics							
Rehabilitation group (%)	Medically complex	30	42	36	1	1	1
	Orthopedic conditions	8	8	8	62	40	59
	Stroke	27	10	20	2	4	2
	Brain dysfunction	13	10	12	6	17	8
	Debility	11	15	13	0	0	0
	Spinal cord dysfunction	2	2	2	27	34	28
	Neurologic conditions	3	4	3	1	3	1
	Cardiac	1	2	1	-	-	-
	Pulmonary	2	3	2	-	-	-
	Others	3	4	3	2	1	1
Rehabilitation active LOS (d), median (IQR)		19 (13.0-28.0)	20 (14.0-28.0)	19 (13.0-28.0)	19.0 (13.0-27.0)	21.0 (13.0-29.0)	19.0 (13.0-28.0)
Discharge disposition (%)	Home with paid health services	65	65	65	67	64	67
	Assisted living	15	16	16	11	9	11
	Residential care	7	7	7	8	9	8
	Acute care	6	7	6	5	7	5
	Home without health services	5	4	5	8	9	8
	Others	2	1	1	2	2	2

Abbreviation: IQR, interquartile range.

Table 2 Descriptive statistics for active and ALC LOS for Medicine and Neuro/MSK categories

			Length of Stay (d), Median (IQR)			
Acute Diagnosis	Patients (n)	Patients With ALC (%)	Acute Active LOS	Acute ALC LOS for ALC Patients	Acute Total LOS	Rehabilitation Active LOS
Medicine	4526	45	8 (5-13)	5 (3-8)	11 (7-17)	18 (12-26)
I60-I69 - Cerebrovascular diseases	807	22	6 (4-10)	5 (3-8)	7 (4-12)	22 (14-33)
J09-J18 - Influenza and pneumonia	230	61	8 (5-13)	5 (3-8)	12 (8-18)	17 (11-24)
F00-F09 - Organic, including symptomatic, mental disorders	217	46	8 (5-14)	6 (3-10)	11 (7-18)	18 (14-27)
A30-A49 - Other bacterial diseases	165	54	12 (8-20)	6 (4-9)	15 (11-24)	21 (14-28)
I30-I52 - Other forms of heart disease	162	53	10 (7-17)	6 (3-9)	14 (10-19)	18 (13-25)
Others	2675	49	8 (5-14)	5 (3-8)	11 (7-18)	19 (13-27)
Neuro/MSK	1871	12	8 (6-12)	5 (3-9)	8 (6-13)	18 (12-26)
S70-S79 - Injuries to the hip and thigh	636	7	8 (6-12)	7 (4-12)	8.5 (6-13)	22 (15-28)
M40-M54 - Dorsopathies	440	14	7 (5-9)	3 (2-6)	7 (6-10)	15 (9.75-23)
M00-M25 - Arthropathies	179	4	6 (4-9)	2 (1.5-6)	6 (4-9)	15 (11-22)
S30-S39 - Injuries to the abdomen, lower back, lumbar spine, pelvis, and external genitals	99	12	8 (5-12)	7 (3.75-8)	8 (5-13)	21 (15-27)
T80-T88 - Complications of surgical and medical care, not elsewhere classified	73	12	9 (6-15)	5 (2-8)	10 (6-16)	22 (15-29)
Others	444	21	10 (6-16)	6 (4-10)	12 (7-19)	21 (13-30)

NOTE. Values are rounded to the closest integer.
Abbreviation: IQR, interquartile range.

experienced discharge delays (non-0 ALC LOS). Patients who had ALC status required more complex care as measured by RIW (1.6 vs 1.3, P value of 2-sided t test<.001) and were more likely to have at least 1 comorbidity (71% vs 64%, P value of χ^2 test<.001) compared with patients without ALC status.

Among the Neuro/MSK category, 63% of the patients were male, the median age was 76 years, 18% of the patients had comorbidity level 2 or more, and 12% experienced delayed discharge. Patients who had ALC status required more complex care as measured by RIW (2.6 vs 1.9, P value of 2-sided t test<.001), but there was no significant difference in the proportion of patients with at least 1 comorbidity (37% vs 33%, P value of χ^2 test=0.1806).

Table 2 provides summary statistics for the acute and rehabilitation LOS stratified by the most responsible diagnosis. The fraction of patients with ALC status varied from 22%-61% for Medicine and from 4%-14% for Neuro/MSK among the top 5 diagnoses. The median ALC LOS (for those with ALC status)

Table 3 Descriptive statistics of rehabilitation outcomes for Medicine and Neuro/MSK patients. Values are rounded to the closest integer.

			Rehabilitation Outcomes		
Acute Diagnosis	Patients (n)	Patients With ALC (%)	Admission FIM Scores	Discharge FIM Scores	Rehabilitation Efficiency
Medicine	4526	45	58 (46-75)	90 (67-104)	1 (1-2)
I60-I69 - Cerebrovascular diseases	807	22	69 (49-85)	102 (83-110)	1 (1-2)
J09-J18 - Influenza and pneumonia	230	61	56 (43-71)	87 (63-99)	1 (1-2)
F00-F09 - Organic, including symptomatic, mental disorders	217	46	48 (37-61)	76 (57-92)	1 (1-2)
A30-A49 - Other bacterial diseases	165	54	56 (47-70)	89 (63-100)	1 (1-2)
I30-I52 - Other forms of heart disease	162	53	57 (45-73)	88 (63-101)	1 (1-2)
Others	2675	49	57 (46-73)	88 (66-103)	1 (1-2)
Neuro/MSK	1871	12	65 (50-80)	101 (84-110)	2 (1-2)
S70-S79 - Injuries to the hip and thigh	636	7	59 (46-75)	98 (76-108)	2 (1-2)
M40-M54 - Dorsopathies	440	14	74 (58-85)	106 (94-112)	2 (1-3)
M00-M25 - Arthropathies	179	4	64 (50-77)	101 (85-108)	2 (1-3)
S30-S39 - Injuries to the abdomen, lower back, lumbar spine, pelvis, and external genitals	99	12	58 (43-79)	95 (77-105)	1.4 (1-2)
T80-T88 - Complications of surgical and medical care, not elsewhere classified	73	12	65 (52-83)	99 (80-106)	1.1 (1-2)
Others	444	21	66 (50-80)	100 (85-110)	1.4 (1-2)

NOTE. Values are rounded to the closest integer.

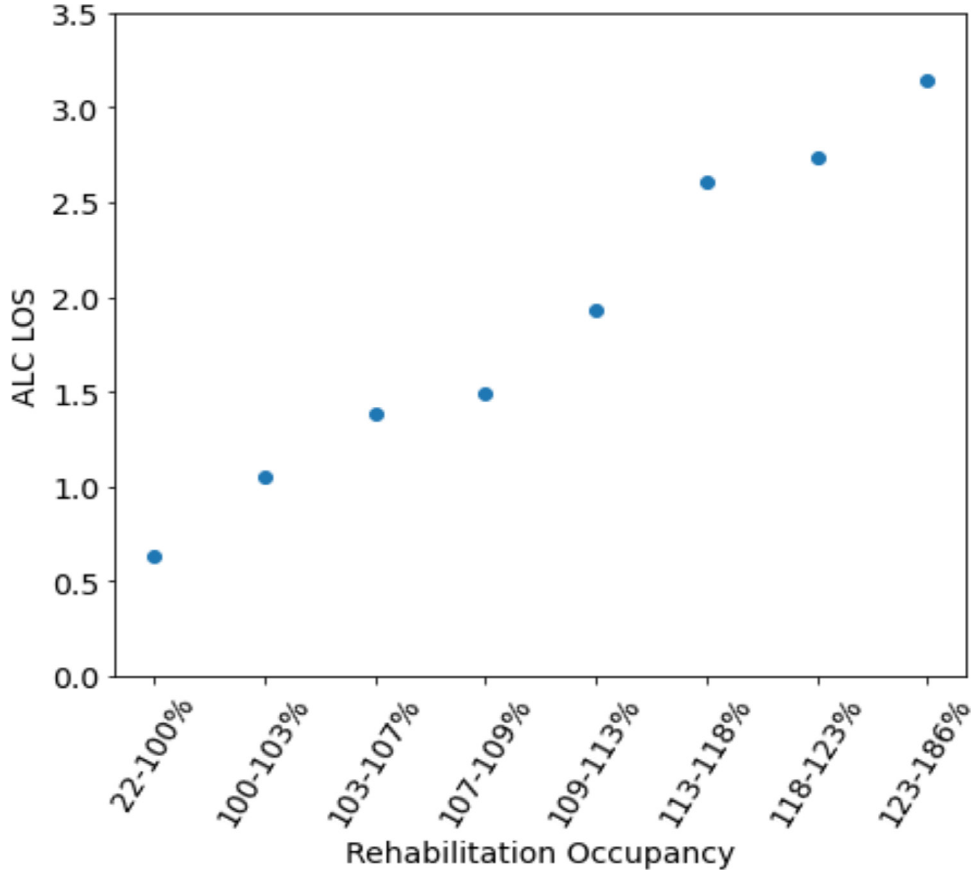

Fig 3 The relation between rehabilitation occupancy and ALC LOS. Each point on the figure presents the average ALC LOS of the patients for the corresponding range of occupancy (including patients on the waiting list) in rehabilitation sites. The bin intervals are selected such that each interval contains the same number of observations.

varied from 5-6 days among the top 5 diagnoses for Medicine and from 2-7 days for Neuro/MSK. The median rehabilitation LOS also varied among the top 5 most responsible diagnoses, from 17-22 for Medicine and from 15-22 for Neuro/MSK.

Table 3 presents summary statistics for rehabilitation outcomes stratified by the top 5 most responsible diagnoses. Outcomes varied across the different diagnoses. In particular, the median admission FIM score varied from 48-69 for Medicine and from 58-65 for Neuro/MSK.

Validity of the instrument

The instrument was highly correlated with the ALC LOS as illustrated in fig 3, that is, patients whose statuses were changed to ALC when the occupancy was higher experienced higher ALC LOS on average. Wald test showed no evidence (P<.001) that the instrument is weak. First-stage estimation similarly indicates a significant correlation (appendix 3, supplemental table S2).

Estimation results

Table 4 provides the estimated coefficient of ALC LOS for different outcomes and for Medicine and Neuro/MSK categories, respectively. Detailed estimation results for all 5 models can be found in appendix 4, supplemental tables S5-17. Based on the results of Model 1, delayed discharge from acute care had a negative and statistically significant association with log rehabilitation active LOS for both categories. One additional day of delayed discharge on average increased the log rehabilitation active LOS of Medicine and Neuro/MSK patients by 0.05 and 0.12, respectively. These values translate to 1- and 2.4-day or equivalently 5.1% (95% confidence interval [CI], 3%-7.3%) and 11.6% (95% CI, 2.8%-20.4%) increase in the rehabilitation active LOS on average.

The effect of delayed discharge on FIM score gain was not statistically significant. All other results were significant (at 0.05 significance level), except the effects on FIM score at discharge from rehabilitation and rehabilitation efficiency for Neuro/MSK patients. One additional day of delayed discharge decreased the admission FIM scores for Medicine and Neuro/MSK patients respectively by 1.43 (95% CI, 0.72-2.13) and 3.11 (95% CI, 0.44-5.78), discharge FIM scores by 1.55 (95% CI, 0.66-2.44) and 2.29 (95% CI, −0.85 to 5.42), and rehabilitation efficiency by 0.08 (95% CI, 0.03-0.13) and 0.08 (95% CI, −0.07 to 0.23) on average. The results were consistent across the other 4 models, although stratified analysis for the top diagnoses suggests that disease-level estimates could vary within each category.

Discussion

Using retrospective data from a large hospital network, we measured the association between delayed discharge from acute care because of capacity strain in rehabilitation, rehabilitation LOS, and functional outcomes for patients of Medicine and Neuro/MSK acute categories. The magnitude of the association with

Table 4 Estimated coefficient of ALC LOS for different outcomes and the Medicine and Neuro/MSK categories

Outcome	Medicine, Coefficient (SE)					Neuro/MSK, Coefficient (SE)				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
AdmFIM	−1.43* (0.36)	−2.06* (0.41)	−1.42* (0.36)	−1.48* (0.36)	−1.43* (0.36)	−3.11* (1.34)	−5.14* (1.68)	−2.79* (1.38)	−3.42* (1.35)	−3.36† (1.41)
DischFIM	−1.55* (0.46)	−1.74* (0.49)	−1.55* (0.45)	−1.62* (0.46)	−1.61* (0.46)	−2.29 (1.58)	−3.44‡ (1.84)	−1.91 (1.63)	−2.20 (1.58)	−2.68‡ (1.64)
FIM Gain	−0.09 (0.30)	0.38 (0.33)	−0.09 (0.30)	−0.12 (0.30)	−0.15 (0.3)	0.65 (1.12)	1.50 (1.27)	0.70 (1.15)	1.04 (1.11)	0.50 (1.16)
RehEff	−0.08* (0.02)	−0.06* (0.02)	−0.08* (0.02)	−0.08* (0.02)	−0.08* (0.02)	−0.08 (0.08)	−0.11 (0.09)	−0.07 (0.08)	−0.08 (0.08)	−0.10 (0.08)
log(RehLOS)	0.05* (0.01)	0.06* (0.01)	0.05* (0.01)	0.05* (0.01)	0.05* (0.01)	0.11* (0.04)	0.18* (0.05)	0.10* (0.04)	0.12* (0.04)	0.11* (0.04)

NOTE. Model 1: log(RehLOS)=age+sex+intervention+rehabilitation category+comorbidity+ALC LOS. Model 2: log(RehLOS)=age+sex+intervention+rehabilitation category+comorbidity+rehabilitation site+ALC LOS. Model 3: log(RehLOS)=age+sex+intervention+rehabilitation category+RIW+ALC LOS. Model 4: log(RehLOS)=age+sex+intervention+rehabilitation category+comorbidity+acute subcategory+ALC LOS. Model 5: log(RehLOS)=age+sex+intervention+rehabilitation category+comorbidity+acute diagnosis+ALC LOS.

Abbreviations: AdmFIM, FIM score at admission to rehabilitation; DischFIM, FIM score at discharge from rehabilitation; RehEff, rehabilitation efficiency; RehLOS, rehabilitation active LOS.

* Statistical significance of the effects=.01.
† Statistical significance of the effects=.05.
‡ Statistical significance of the effects=.1.

rehabilitation LOS was substantial for both categories but larger for Neuro/MSK. We also found a negative association with FIM scores at admission and discharge, but the magnitude was relatively small. There was no significant association with the absolute improvement in functionality. However, there was significant negative association with rehabilitation efficiency for Medicine patients.

Our results have important implications for reducing discharge delays from acute care and improving rehabilitation efficiency. The observation that delayed transition because of capacity strain increases rehabilitation LOS points to a "cascading" effect for delays: delayed patients occupy rehabilitation beds longer, hence further contributing to capacity strain and leading to additional delays in transition for future patients. These delays can also be negatively associated with functional scores of patients at both admission and discharge. Combining the 2 effects, 1 additional day of delayed discharge is associated with a 0.08 decrease in per day improvement in functional capabilities of patients. Therefore, increasing the bottleneck capacity in rehabilitation (beds or staff) and streamlining the admission process to reduce capacity-driven delays can be highly effective in improving the patient flow and rehabilitation outcomes. In particular, reducing capacity-driven delays not only reduces patients' acute LOS, allowing more patients to get timely access to acute care, but also reduces patients' rehabilitation LOS, improving the throughput of rehabilitation.

There are 2 potential sources of bias in standard OLS estimation (without IV). First, even though we controlled for some patient severity information, there are likely unobserved patient severity-related characteristics. In general, patients with more severe conditions could be more likely to experience a longer delay and are also more likely to require a longer rehabilitation LOS. This unobserved patient severity information is likely to cause an overestimation of the magnitude of the effect of capacity-driven delays. Second, ALC LOS may include both noncapacity-driven and capacity-driven delays. Noncapacity-driven delays could potentially improve patient outcomes by preparing the patient for rehabilitation. Not being able to separate the 2 types of delays is likely to cause an underestimation of the magnitude of the effect of capacity-driven delay. Compared with the OLS estimates, the magnitudes of the coefficient for acute ALC LOS with IV were larger (appendix 4, supplemental tables S3 and S4). This suggests that the effect of the second bias is dominating. These results also highlight the importance of removing biases due to unobserved confounders.

Study limitations

Our study has several limitations: (1) We measure delays using the amount of time a patient has ALC status. The timing of ALC designation is decided by the acute physician. As such, our measurement of discharge delay is subject to under- or overreporting. Overreported delays would imply that the effect of delays is even larger than estimated in our study, while underreported delays mean that our estimates can be inflated. However, our results from Model 2 suggest that our findings are consistent across sites and hence possibly not sensitive to variations in assigning ALC status. (2) Our study used data from 2 sites of a single institution and for its 2 largest acute care categories. The robustness of our observations to other institutions and for other acute categories should be investigated in future research. (3) We did not control for intensity of the rehabilitation, which could affect discharge FIM scores.

However, we expect the intensity to be independent of the rehabilitation occupancy, and hence the IV approach should adjust for the potential bias. An examination of this requires granular data on the rehabilitation intensity. (4) Our study population was highly heterogeneous. Although our analysis suggests that estimates of the average effects across acute categories are robust, the estimates may differ at the disease level. Estimating disease-specific effects requires larger samples for different diagnoses and should be investigated in future research.

Conclusions

Our study identified an association between delayed discharge from acute care because of capacity strain in rehabilitation, prolonged LOS, and lower efficiency in rehabilitation. Reducing capacity strain in rehabilitation by expanding capacity to eliminate delays could be highly effective in reducing discharge delays in acute care and increasing the efficiency of rehabilitation. Because of the observed cascading effect of delays, even a small reduction in capacity-driven delays could lead to a substantial improvement in rehabilitation efficiency and availability of bed capacity in acute care.

Keywords

Patient admission; Rehabilitation

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References

1. Sutherland JM, Crump RT. Alternative level of care: Canada's hospital beds, the evidence and options. Healthc Policy 2013;9:26–34.
2. Costa AP, Poss JW, Peirce T, Hirdes JP. Acute care inpatients with long-term delayed discharge: evidence from a Canadian health region. BMC Health Serv Res 2012;12:1–10.
3. Victor CR, Healy J, Thomas A, Seargeant J. Older patients and delayed discharge from hospital. Health Soc Care Community 2000;8:443–52.
4. Bryan K. Policies for reducing delayed discharge from hospital. Br Med Bull 2010;95:33–46.
5. Alcone D, Bolda E, Leak SC. Waiting for placement: an exploratory analysis of determinants of delayed discharges of elderly hospital patients. Health Serv Res 1991;26:339–94.
6. Canadian Institute for Health Information. Guidelines to support ALC designation. Available at: https://www.cihi.ca/en/guidelines-to-support-alc-designation. Accessed October 19, 2021.
7. Canadian Institute for Health Information. Hospital stays in Canada. Available from: https://www.cihi.ca/en/hospital-stays-in-canada. Accessed April 15, 2022.
8. Sumida M, Fujimoto M, Tokuhiro A, Tominaga T, Magara A, Uchida R. Early rehabilitation effect for traumatic spinal cord injury. Arch Phys Med Rehabil 2001;82:391–5.
9. Munin MC, Rudy TE, Glynn NW, Crossett LS, Rubash HE. Early inpatient rehabilitation after elective hip and knee arthroplasty. JAMA 1998;279:847–52.
10. Spettell CM, Ellis DW, Ross SE, et al. Time of rehabilitation admission and severity of trauma: effect on brain injury outcome. Arch Phys Med Rehabil 1991;72:320–5.
11. Heinemann AW, Linacre JM, Wright BD, Hamilton BB, Granger C. Prediction of rehabilitation outcomes with disability measures. Arch Phys Med Rehabil 1994;75:133–43.
12. Heinemann AW, Hamilton B, Linacre JM, Wright BD, Granger C. Functional status and therapeutic intensity during inpatient rehabilitation. Am J Phys Med Rehabil 1995;74:315–26.
13. Wang H, Camicia M, Terdiaman J, Hung Y, Sandel ME. Time to inpatient rehabilitation hospital admission and functional outcomes of stroke patients. PM R 2011;3:296–304.
14. Salter K, Jutai J, Hartley M, et al. Impact of early vs delayed admission to rehabilitation on functional outcomes in persons with stroke. J Rehabil Med 2006;38:113–7.
15. Sirois MJ, Lavoie A, Dionne CE. Impact of transfer delays to rehabilitation in patients with severe trauma. Arch Phys Med Rehabil 2004;85:184–91.
16. Canadian Institute for Health Information. CMG+. Available at: https://www.cihi.ca/en/cmg. Accessed August 3, 2021.
17. Linacre JM, Heinemann AW, Wright BD, Granger CV, Hamilton BB. The structure and stability of the Functional Independence Measure. Arch Phys Med Rehabil 1994;75:127–32.
18. Wooldridge JM. Econometric analysis of cross section and panel data. 2nd ed. Cambridge, MA: MIT Press; 2010.
19. Newhouse JP, McClellan M. Econometrics in outcomes research: the use of instrumental variables. Annu Rev Public Health 1998;19:17–34.
20. Momosaki R, Yasunaga H, Matsui H, Horiguchi H, Fushimi K, Abo M. Effect of early rehabilitation by physical therapists on in-hospital mortality after aspiration pneumonia in the elderly. Arch Phys Med Rehabil 2015;96:205–9.