The Role of Long-term Acute Care Hospitals in Treating the Critically Ill and Medically Complex

An Analysis of Nonventilator Patients

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Background: Little evidence exists on the effects of receiving care in a long-term acute care hospital (LTCH).

Objective: To examine LTCH effects on mortality and Medicare payments overall and among high-acuity patients.

Research Design: A retrospective cohort study of Medicare beneficiaries using probit and generalized linear models. An instrumental variable technique was used to adjust for selection bias.

Subjects: Medicare beneficiaries within 5 major diagnostic categories and not on prolonged mechanical ventilation.

Measures: Mortality (365 d) and Medicare payments (180 d) during an episode of care.

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Results: LTCH care is associated with increases in Medicare payments ranging from \$3146 to \$17,589 ($P < 0.01$) with no mortality benefit for 3 categories and payment reductions of \$5419 and \$5962 ($P < 0.01$) at lower or similar mortality for 2 categories. LTCH patients with multiple organ failure experience lower mortality at similar or lower payments (3 categories) or similar mortality at lower payments (1 category) compared with patients in other settings, with mortality benefits between 5.4 and 9.7 percentage points ($P < 0.05$) and payment reductions between \$13,806 and \$20,809 ($P < 0.01$). For 1 category, we found no difference in mortality or payments between LTCH and non-LTCH patients with multiple organ failure. For patients with ≥ 3 days in intensive care, LTCH care is associated with improved mortality and lower payments in 4 and 3 categories, respectively.

Conclusions: Receiving care in an LTCH may improve outcomes for some patients. Further research is needed to better define patients for whom care in these hospitals is beneficial.

Key Words: Medicare, cost, payments, mortality, hospital, post acute care, intensive care, organ failure, effectiveness

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Critically ill and medically complex patients are expected to represent a growing segment of the Medicare population due to the aging of the population, growing prevalence of chronic conditions, and advances in critical care.^{1,2} Because they consume significant health care resources, a key area for research is identifying cost-effective approaches for treating these patients. Long-term acute care hospitals (LTCHs) represent a potentially important care setting for critically ill and medically complex patients. To be certified as an LTCH under Medicare, a provider must meet the same conditions of participation as a short-term acute care hospital (ACH) but have a mean length of stay of ≥ 25 days.³

The use of LTCHs in Medicare varies dramatically by region. Among all Medicare fee-for-service (FFS) hospital discharges, for example, the percent discharged from an LTCH was 8.5 times higher in Texas than New York.⁴ To some extent, such substantial geographic variation is likely driven by nonpatient factors, such as payment policies, regulations, and provider practice patterns. Some states have few or no LTCHs due, in part, to state certificate-of-need requirements.⁵ The uneven geographic availability of LTCHs indicates that critically ill and medically complex cases may be appropriately treated in other, lower cost settings, raising questions as to the value of LTCHs.⁵

The impact of LTCH use on Medicare beneficiaries and the program itself, however, is unclear due to a lack of empirical evidence. Recent legislation requiring the Centers for Medicare & Medicaid Services (CMS) to implement patient criteria for LTCHs heightens the need to address questions on LTCH efficacy and cost. It is expected that these new criteria, once fully implemented in 2018, will reduce Medicare payments by >50% for cases not meeting the criteria, which represented almost half of all LTCH cases in 2012.⁶ These changes may result in reduced Medicare beneficiary access to LTCHs for some patients.

In this study, we examine the effects of LTCH care on mortality and payments for Medicare patients. While prior research on the effects of LTCH care has focused on patients requiring prolonged mechanical ventilation,^{7,8} we are unaware of published research on other patient populations. To fill this gap, we examine patient outcomes for the 5 most common major diagnostic categories within the non-ventilator LTCH patient population. We further assess whether the effects of receiving care in an LTCH differ for patients with certain characteristics relating to severity and complexity prevalent in the LTCH population.

METHODS

Overview of Study Design and Data Sources

We conducted a retrospective cohort study of Medicare beneficiaries to compare mortality and Medicare payments for patients transferred to an LTCH immediately following discharge from an ACH and those receiving care in other settings. We estimated the effects of receiving care in an LTCH using an instrumental variable approach that controlled for potential selection bias due to unmeasured severity.

We examined Medicare payments and mortality over the course of a patient episode. For Medicare payments, the episode starts at date of admission to an ACH and ends at patient death or 180 days after admission. In modeling mortality, we started the episode “clock” at the geometric mean time to transfer to an LTCH within the patient’s MS-DRG and examined mortality over the next 365 days or until death. By shortening the time between the start of an episode and LTCH transfer and increasing the episode length, we sought to reduce the magnitude of immortal time bias that arises in mortality studies where determination of treatment status (transfer to LTCH) occurs after a wait period following the ACH admission.⁹

An ACH stay can only start an episode if a patient does not have another ACH admission for the same reason, as determined by major diagnostic category (MDC), during the previous 60 days. Readmissions to ACH during the episode period are taken into account in computing episode outcomes. A stay in an ACH that starts an episode is referred to as an index ACH admission.

The primary data sources for our study were the 2009–2011 Inpatient, Skilled Nursing Facility, and Home Health Agency Standard Analytic Files available from the CMS. These databases include 100% Medicare FFS claims for all ACHs, LTCHs, inpatient rehabilitation facilities, skilled nursing facilities, and home health agencies between January 1, 2009 and December 31, 2011.¹⁰ Patient demo-

graphic data were pulled from the Denominator File.¹¹ Additional hospital-level and market area covariates and instruments were constructed using the FY 2011 Inpatient Prospective Payment System Impact File, 2011 Hospital Compare database, 2012 Area Health Resource File, 2012 Provider of Services File, and the Dartmouth Atlas.^{12–16}

Populations Studied, With Inclusion and Exclusion Criteria

We conducted our analyses on patients within 5 MDCs based on the MS-DRG for the index ACH stay: respiratory (MDC 4), circulatory (MDC 5), digestive (MDC 6), musculoskeletal and connective tissue (MDC 8), and infectious and parasitic diseases and disorders (DDs) (MDC 18). We used MDCs to capture a substantial portion of LTCH patients in the study sample while limiting the number of different models. These 5 MDCs are the most common among the LTCH patient population not receiving prolonged mechanical ventilation (nonventilator) and constitute 47% and 58% of all and non-ventilator LTCH cases in 2012, respectively. We excluded patients who were assigned to an MS-DRG based on receiving prolonged mechanical ventilation during their index ACH stay (MS-DRG: 207, 208, or 870) or had an ICD-9 procedure code for continuous mechanical ventilation lasting >96 hours (ICD-9 code: 96.72).¹⁷ To focus on an elderly population with sufficient claims experience in Medicare, we included patients who were 67 or older at the time of discharge from the index ACH stay and who had both Medicare Part A and B coverage for 6 months before and after the month in which the discharge from the index ACH occurred. Furthermore, we excluded patients who died before the MS-DRG-specific geometric mean time to transfer to an LTCH to reflect a population likely to have had an opportunity for postacute care transfer. The derivation of the sample is shown in Table 1.

Outcome and Explanatory Variables

The primary outcomes examined are all-cause mortality and total payments from the Medicare Hospital Insurance Trust Fund during an episode of care. The key explanatory variable is transfer from the index ACH to LTCH. We defined an episode as having an LTCH transfer if a patient is discharged from the index ACH on day *n* and admitted to an LTCH on day *n* or *n*+1. All other episodes not meeting this definition comprise the comparison group. We included patient-level and index ACH-level control variables in the analysis to adjust for observed (measured) differences between LTCH and non-LTCH patients and control for the variation in patient illness and severity within an MDC. These variables include patient demographics, measures of condition severity, MS-DRG, treatments, and the comorbid condition categories developed by Horwitz et al¹⁸ based on CMS Condition Categories (see Appendix A, Supplemental Digital Content 1, <http://links.lww.com/MLR/A953>).

We also explored outcome differences for patients who spent ≥3 days in an intensive or cardiac care unit (ICU/CCU) during the index ACH stay and patients who had multiple organ failure. Three or more days in ICU/CCU and multiple organ failure were 2 of the most common clinical characteristics among LTCH patients with 51% and 45% of

TABLE 1. Derivation of Study Sample

Exclusion Criteria*	Possible Index Admissions Before Applying Criteria	Claims Dropped Due to Criteria
No charges or no Medicare paid days [†]	36,601,194	1,382,677
Discharged from facility other than ACH [‡]	35,218,517	4,029,682
Discharged against medical advice [§]	31,188,835	224,006
Beneficiary not listed in denominator file	30,964,829	25,088
Under age 67 [¶]	30,939,741	7,997,989
Admitted before July 1, 2009 or after June 30, 2011 [¶]	22,941,752	7,686,818
Without 13 mo of continuous Part A and B coverage [¶]	15,254,934	868,628
Overlapping hospital stays [#]	14,386,306	37,372
Primary payer other than Medicare [†]	14,348,934	15,172
Prior admission for same condition within prior 60 d ^{**}	14,333,762	1,188,315
Assigned to ventilator MS-DRG ^{††}	13,145,447	169,163
MS-DRG not included within MDCs 04, 05, 06, 08, and 18 ^{**}	12,976,284	4,175,086
Had prolonged ventilation based on ICD-9 procedure code ^{††}	8,801,198	65,718
Died before MS-DRG geometric mean time to transfer to an LTCH [†]	8,735,480	320,571
Incomplete data	8,414,909	300,428
Final sample size	8,114,481	

*Criteria are listed in the order in which they were applied.

[†]These criteria were applied to remove patients possessing non-Medicare primary coverage. For such patients, a significant portion of their medical utilization may not be included in Medicare administrative data.

[‡]These criteria limit the sample to a homogenous pool of candidates for postacute care.

[§]Medical outcomes for cases discharged against medical advice cannot necessarily be attributed to the care provided.

^{||}These criteria were applied to remove episodes with incomplete information.

[¶]These criteria limited the sample to patients with sufficient experience in the Medicare fee-for-service program.

[#]Overlapping stays are indicative of data errors.

^{**}A recent prior admission for the same condition indicates that this claim is not the start of a medical episode.

^{††}This study was focused on the 5 most common MDCs among the nonventilator LTCH patient population.

^{††}We excluded cases with continuous invasive mechanical ventilation for 96 consecutive hours or more identified by the ICD-9 procedure code of 96.72.

LTCH indicates long-term acute care hospital.

LTCH patients in the combined study sample having these characteristics, respectively. In addition, recent legislation requires that a patient receive ≥ 3 ICU/CCU days in an ACH immediately before admission to an LTCH to qualify for full LTCH payment.

The number of ICU/CCU days were based on unit counts associated with revenue centers 020X and 021X, which include codes covering intermediate care units and are consistent with the definition of ICU/CCU days outlined in recent legislation establishing LTCH patient criteria. We classified patients as having multiple organ failure if they had at least 2 of the following 4 organ failures: heart failure, acute renal failure, acute and subacute necrosis of liver, and cardiopulmonary failure (see Appendix A, Supplemental Digital Content 1, <http://links.lww.com/MLR/A953>).

Estimation Strategy

Patients transferred to LTCHs tend to be more severely ill and medically complex than patients treated at other postacute care settings, in ways not observable from administrative data. While a multivariate regression approach and propensity score matching control for measured differences between the 2 groups, unmeasured differences may remain, leading to selection bias, and threatening the internal validity of study findings. To adjust for any unmeasured differences between LTCH and non-LTCH patients due to

sample selection, we use the instrumental variables method, which has been widely used in health services research.^{19,20}

We use the 2-stage residual inclusion technique (2SRI), which is a 2-stage estimator that relies on instruments to control for selection bias when the outcomes of interest are nonlinear functions of observed and unobserved variables.²¹ In the first stage of the 2SRI method, the LTCH transfer status is regressed on observable control variables and instrumental variables. In the second stage, the outcomes are regressed on LTCH transfer status, observable control variables and the response residuals from the first-stage regressions. We used distance between the admitting ACH and the nearest LTCH, calculated based on driving distance using Bing[®] maps, and the number of LTCHs within a beneficiary's hospital referral region as instrumental variables in the analysis. Diagnostic tests provide support for the validity of our instruments for all condition categories except the musculoskeletal and connective tissue category, for which instrument exogeneity was only weakly supported in the mortality model (Appendix B, Supplemental Digital Content 2, <http://links.lww.com/MLR/A954>). For the musculoskeletal and connective tissue category, we conducted sensitivity analysis of the mortality model using a different set of instruments and obtained findings similar to the ones presented in this paper (Appendix C, Supplemental Digital Content 3, <http://links.lww.com/MLR/A955>).

TABLE 2. Postacute Care Transfers*

	Total [N (%)]				
	MDC = 04 (Respiratory)	MDC = 05 (Circulatory)	MDC = 06 (Digestive)	MDC = 08 (Musculoskeletal and Connective Tissue)	MDC = 18 (Infectious and Parasitic DDs)
LTCH	17,533 (1.0)	15,314 (0.5)	9701 (0.7)	9304 (0.5)	19,221 (3.3)
SNF	361,224 (21.6)	432,633 (15.4)	228,796 (17.1)	721,975 (42.0)	193,605 (33.4)
IRF	23,665 (1.4)	54,091 (1.9)	18,280 (1.4)	194,292 (11.3)	12,429 (2.1)
Deceased	19,192 (1.1)	13,352 (0.5)	7996 (0.6)	4875 (0.3)	18,068 (3.1)
Other†	1,254,248 (74.8)	2,290,163 (81.6)	1,071,287 (80.2)	787,225 (45.8)	336,012 (58.0)
Total	1,675,862 (100.0)	2,805,553 (100.0)	1,336,060 (100.0)	1,717,671 (100.0)	579,335 (100.0)

*Percentages for an MDC may not add to 100% due to rounding.

†Other includes discharges to home, home care of home health service organization, and hospice.

IRF indicates inpatient rehabilitation facility; LTCH, long-term acute care hospital; MDC, major diagnostic category; SNR, skilled nursing facility.

We used probit regression to model the mortality outcome and a generalized linear model with log link and gamma distribution to model Medicare payments. We investigated the existence of differential LTCH effects, using expanded model specifications that included interaction terms between LTCH transfer and ≥ 3 days in an ICU/CCU and whether a patient has multiple organ failure. We estimated robust SEs with clustering at the index ACH level in all regressions. We also conducted a sensitivity analysis, excluding from our study sample those with relatively low predicted probability of LTCH transfer (Appendix C, Supplemental Digital Content 3, <http://links.lww.com/MLR/A955>).

To assess the extent to which immortal time bias might impact our findings, we computed the magnitude of the immortal time bias based on the quantification strategy

outlined in Suissa.⁹ We found that the ratio of biased rate ratio to unbiased rate ratio is over 98% in all episode groups, providing evidence that the magnitude of the bias is very small in our analyses (see Appendix D, Supplemental Digital Content 4, <http://links.lww.com/MLR/A956>).

RESULTS

Our study sample sizes ranged from 579,335 patients with the infectious and parasitic DDs to 2,805,553 patients with circulatory problems (Table 2). The percent of patients receiving postacute care in an LTCH were 3.3% in the infectious and parasitic DDs category, 1% in the respiratory category, and <1% of the patients in the remaining categories. Patients who transfer to LTCHs are more likely to be male and

TABLE 3. Descriptive Statistics

	MDC = 04 (Respiratory) N = 1,675,862		MDC = 05 (Circulatory) N = 2,805,553		MDC = 06 (Digestive) N = 1,336,060		MDC = 08 (Musculoskeletal and Connective Tissue) N = 1,717,671		MDC = 18 (Infectious and Parasitic DDs) N = 579,335	
	LTCH	Non-LTCH	LTCH	Non-LTCH	LTCH	Non-LTCH	LTCH	Non-LTCH	LTCH	Non-LTCH
Patient characteristics										
Demographic characteristics										
Age (mean)	79.4	79.4	78.8	79.3	79.1	79.1	78.9	78.4	79.0	79.9
Male (%)	46.1	42.7	48.1	45.3	40.2	37.9	42.0	32.9	45.6	44.3
Race (%)										
White	80.5	87.6	76.6	85.9	77.3	86.1	82.2	91.8	71.9	84.6
Black	11.9	8.0	16.5	9.8	16.0	9.4	12.5	5.1	19.0	10.0
Other	7.6	4.5	6.9	4.2	6.8	4.6	5.3	3.2	9.1	5.4
Clinical characteristics										
No. days in ICU/CCU (mean)	4.0	1.6	6.7	2.2	6.9	1.4	2.9	0.5	5.2	2.6
≥ 3 d in ICU/CCU (%)	46.3	23.3	60.6	31.4	59.5	19.0	30.5	8.1	56.3	33.2
Multiple organ failure (%)	45.9	26.5	58.5	27.3	37.5	13.7	27.2	6.7	44.8	30.6
Stroke or TBI (%)	3.8	1.9	6.1	2.1	4.3	1.7	3.5	1.7	1.3	3.5
Sepsis (%)	13.3	4.5	20.4	3.3	28.3	5.1	16.0	4.1	89.1	84.3
Wounds or ulcers (%)	15.6	5.9	30.5	6.9	25.7	5.7	32.7	0.8	43.7	24.1
≥ 3 MCCs (%)	9.1	1.7	23.5	2.2	28.0	2.2	12.6	0.8	33.1	14.2
Outcomes										
365 d mortality rate (%)	59.7	32.6	54.9	21.9	50.5	20.6	39.2	12.5	55.6	38.3
180 d Medicare payment (mean)	60,420	21,081	74,449	22,858	79,322	20,751	75,499	27,520	73,319	29,400

CCU indicates cardiac care unit; DD, diseases and disorders; ICU, intensive care unit; LTCH, long-term acute care hospital; MCC, major complications or comorbidities; MDC, major diagnostic category; TBI, traumatic brain injury.

black compared with those who receive care in a non-LTCH setting (Table 3). Patients treated in LTCHs experienced longer stays in an ICU or CCU on average and are more likely to have multiple organ failure, stroke or traumatic brain injury, sepsis, wounds or ulcers, and complicating or comorbid conditions. Both unadjusted mean 365-day mortality rate and 180-day episode Medicare payments are higher for LTCH patients in all condition categories.

Estimation results of the baseline mortality model, presented in column A of Table 4, show that in the digestive category LTCH patients experience a 2.9 percentage point lower adjusted mortality rate than patients receiving care in other settings. In the remaining 4 condition categories, we found no statistically significant association between LTCH care and adjusted patient mortality.

The expanded mortality model results, presented in columns B1–C3 of Table 4, show that in many of the condition categories, the baseline mortality model results mask statistically significant differences in LTCH effects across patient groups defined by multiple organ failure and ICU/CCU stay. In the musculoskeletal and connective tissue, circulatory, and respiratory categories, LTCH care is associated with lower mortality for patients with multiple organ failure, whereas it has a positive or statistically insignificant relationship with mortality for other patients, generating statistically significant differences in marginal effects between patients with and without multiple organ failure. In the remaining 2 categories, the difference in marginal LTCH effects between patients with and without multiple organ failure is statistically insignificant. Furthermore, compared with similar patients treated in non-LTCH settings, LTCH patients with ≥ 3 days in an ICU/CCU have lower average adjusted mortality, whereas other patients had higher or similar ($P > 0.05$) average adjusted mortality in 4 of the 5 MDCs. In the digestive category, LTCH care has no statistically significant relationship with mortality for patients with ≥ 3 days in an ICU/CCU, and it is associated with lower mortality among other patients.

When cases with low predicted propensity for LTCH transfer are excluded from the analysis, we find similar findings for the majority of the MCDs (Appendix C, Supplemental Digital Content 3, <http://links.lww.com/MLR/A955>). In the baseline model for all MDCs, we find no statistically significant relationship between receiving care in an LTCH and 365-day mortality. The LTCH effects for patients with multiple organ failure or ≥ 3 days in ICU/CCU are robust to changes in our analysis sample with the exception that the relationship between LTCH care and mortality is no longer statistically significant for patients with multiple organ failure in the musculoskeletal and connective tissue category.

Patients transferred to an LTCH experience higher Medicare payments in respiratory, musculoskeletal and connective tissue, and infectious and parasitic DDs categories, with the magnitude of the LTCH effect ranging between \$3146 and \$17,589 (column A of Table 5). For circulatory and digestive categories, receiving care in an LTCH is associated with lower mean adjusted Medicare payments with reductions of \$5962 and \$5419, respectively.

Results presented in columns B1–C3 of Table 5 provide evidence of differential effects of LTCH care on 180-day

Medicare payments for patients with multiple organ failure and minimum 3-day ICU/CCU stay. In 3 condition categories (circulatory, digestive, and musculoskeletal and connective tissue), patients with multiple organ failure who receive post-acute care in an LTCH experience adjusted episode payment reductions between \$13,806 and \$20,809, whereas LTCH patients without multiple organ failure experience higher Medicare payments. In the respiratory and infectious and parasitic DDs categories, LTCH care is not associated with changes in Medicare payments ($P > 0.05$) for patients with multiple organ failure, whereas it is positively related to Medicare payments for those without multiple organ failure.

The marginal effect of LTCH care on Medicare payments is positive but smaller in magnitude for patients with ≥ 3 days in an ICU/CCU compared with other patients in the respiratory and infectious and parasitic DDs categories. In the digestive category, LTCH patients with ≥ 3 days in an ICU/CCU experience similar reductions as other LTCH patients. In the remaining 2 categories (circulatory and musculoskeletal and connective tissue), LTCH care is associated with lower Medicare payments for patients with ≥ 3 days in an ICU/CCU, whereas it is related to similar or higher Medicare payments for patients with < 3 days in an ICU/CCU. The payment model results were robust to excluding from the study sample those with very low predicted probability to transfer to an LTCH (Appendix C, Supplemental Digital Content 3, <http://links.lww.com/MLR/A955>). A comparative graphical presentation of mortality and payment results is included in Figures 1–3.

DISCUSSION

Overall, we find favorable results for LTCH care in terms of patient mortality and Medicare payments for 2 of the 5 major diagnostic categories (circulatory and digestive systems). In these cases, patients treated in LTCHs, as compared with other settings, have similar or lower risk of mortality at lower cost to Medicare. For the 3 remaining categories, LTCH patients have similar mortality but higher Medicare payment relative to patients treated in other settings. We also find the effects of LTCH care tend to be more favorable for patients with either multiple organ failure or ≥ 3 days in an ICU/CCU as compared with patients without these characteristics. In 4 of the 5 condition categories, among patients with multiple organ failure, LTCH care is associated with lower mortality at similar or lower Medicare payment or lower Medicare payment at similar mortality as compared with patients cared for at other settings. We find a similar outcome for patients with ≥ 3 days in an ICU/CCU in 3 of the 5 condition categories. In the remaining 2 categories, LTCH care is associated with lower mortality at higher Medicare payment for patients with minimum 3-day ICU/CCU stay relative to other settings.

Few studies have examined the effects of LTCH care on mortality and Medicare payments, and we are not aware of any appearing in the peer-reviewed literature that focused on the nonventilator patient population. An analysis by MedPAC using claims data from 2001 that included patients from 11 diagnostic categories found no clear mortality benefit from

TABLE 4. Marginal Effect of LTCH on Probability of 365-Day Mortality

Condition Group	Baseline Model	Interaction With Organ Failure			Interaction With ICU/CCU		
	Model Without Interactions (A)	Multiple Organ Failure (B1)	No Multiple Organ Failure (B2)	Difference in Marginal Effects (B3)	ICU/CCU ≥ 3 (C1)	ICU/CCU < 3 (C2)	Difference in Marginal Effects (C3)
MDC= 04 (Respiratory) N = 1,675,862	-0.008 (0.772)	-0.097 (0.001)	0.093 (0.011)	-0.190 (0.000)	-0.123 (0.000)	0.093 (0.054)	-0.216 (0.000)
MDC= 05 (Circulatory) N = 2,805,553	-0.016 (0.259)	-0.072 (0.002)	0.042 (0.037)	-0.114 (0.000)	-0.072 (0.000)	-0.001 (0.958)	-0.070 (0.015)
MDC= 06 (Digestive) N = 1,336,060	-0.029 (0.018)	-0.036 (0.133)	-0.030 (0.035)	-0.006 (0.821)	-0.010 (0.561)	-0.137 (0.000)	0.127 (0.000)
MDC= 08 (Musculoskeletal and connective tissue) N = 1,717,671	-0.003 (0.786)	-0.054 (0.047)	0.011 (0.309)	-0.066 (0.015)	-0.082 (0.000)	0.023 (0.081)	-0.105 (0.000)
MDC= 18 (Infectious and parasitic DDs) N = 579,335	-0.010 (0.560)	-0.008 (0.702)	-0.012 (0.531)	0.004 (0.853)	-0.098 (0.000)	0.131 (0.000)	-0.229 (0.000)

P-values are in parentheses. Marginal LTCH effect is calculated as the average of individual marginal effects that are computed for each observation using the results of the 2-stage residual inclusion regression and the individual observation's covariate values, while varying LTCH indicator between 0 and 1. The baseline model includes the LTCH transfer indicator, patient-level controls, and index ACH-level controls listed in Appendix A as explanatory variables. The model with interaction with organ failure includes an interaction term between LTCH transfer indicator and a multiple organ failure indicator as an additional explanatory variable. The model with interaction with ICU/CCU includes an interaction term between LTCH transfer indicator and indicator for minimum 3-day ICU/CCU stay as an additional explanatory variable. Columns B1 and C1 present marginal effect of LTCH on the outcome among patients with multiple organ failure and minimum 3-day ICU/CCU stay, respectively. Columns B2 and C2 present the marginal effect of LTCH among other patients. Columns B3 and C3 present the differential treatment effect between patients with and without the specified characteristics.

CCU indicates cardiac care unit; DD, diseases and disorders; ICU, intensive care unit; LTCH, long-term acute care hospital; MDC, major diagnostic category.

TABLE 5. Marginal Effect of LTCH on Total Payment for 180-Day Episode

Condition Group	Baseline Model	Interaction With Organ Failure			Interaction With ICU/CCU		
	Model Without Interactions (A)	Multiple Organ Failure (B1)	No Multiple Organ Failure (B2)	Difference in Marginal Effects (B3)	ICU/CCU ≥ 3 (C1)	ICU/CCU < 3 (C2)	Difference in Marginal Effects (C3)
MDC = 04 (Respiratory) N = 1,675,862	17,589 (0.000)	3104 (0.114)	46,364 (0.000)	-43,260 (0.000)	11,326 (0.000)	32,313 (0.000)	-20,987 (0.000)
MDC = 05 (Circulatory) N = 2,805,553	-5962 (0.000)	-18,358 (0.000)	18,200 (0.000)	-36,558 (0.000)	-8262 (0.000)	-2317 (0.164)	-5946 (0.000)
MDC = 06 (Digestive) N = 1,336,060	-5419 (0.000)	-20,809 (0.000)	3768 (0.003)	-24,577 (0.000)	-6850 (0.000)	-6978 (0.000)	129 (0.927)
MDC = 08 (Musculoskeletal and connective tissue) N = 1,717,671	3146 (0.009)	-13,806 (0.000)	11,283 (0.000)	-25,089 (0.000)	-5970 (0.002)	9882 (0.000)	-15,853 (0.000)
MDC = 18 (Infectious and parasitic DDs) N = 579,335	16,855 (0.000)	1611 (0.423)	37,100 (0.000)	-35,489 (0.000)	14,669 (0.000)	26,228 (0.000)	-11,559 (0.002)

P-values are in parentheses. Marginal LTCH effect is calculated as the average of individual marginal effects that are computed for each observation using the results of the 2-stage residual inclusion regression and the individual observation's covariate values, while varying LTCH indicator between 0 and 1. The baseline model includes the LTCH transfer indicator, patient-level controls, and index ACH-level controls listed in Appendix A as explanatory variables. The model with interaction with organ failure includes an interaction term between LTCH transfer indicator and a multiple organ failure indicator as an additional explanatory variable. The model with interaction with ICU/CCU includes an interaction term between LTCH transfer indicator and indicator for minimum 3-day ICU/CCU stay as an additional explanatory variable. Columns B1 and C1 present marginal effect of LTCH on the outcome among patients with multiple organ failure and minimum 3-day ICU/CCU stay, respectively. Columns B2 and C2 present the marginal effect of LTCH among other patients. Columns B3 and C3 present the differential treatment effect between patients with and without the specified characteristics.

CCU indicates cardiac care unit; DD, diseases and disorders; ICU, intensive care unit; LTCH, long-term acute care hospital; MDC, major diagnostic category.

FIGURE 1. Marginal LTCH effects on 365-day mortality and 180-day Medicare payments. The figure illustrates the baseline marginal effect estimates presented in Tables 4 and 5. Error bars show the 95% confidence intervals. LTCH indicates long-term acute care hospital.

FIGURE 2. Marginal LTCH effects by multiple organ failure status. The figure illustrates the differential marginal effects based on multiple organ failure status that are presented in Tables 4 and 5. Error bars show the 95% confidence intervals. LTCH indicates long-term acute care hospital.

FIGURE 3. Marginal LTCH effects by ≥ 3 day ICU/CCU stay status. CCU indicates cardiac care unit; ICU, intensive care unit; LTCH, long-term acute care hospital.

LTCH care.²² In the same analysis, MedPAC found that Medicare payments over an episode are higher for patients treated in LTCHs overall, but not statistically different for the most severely ill patients. Our study differed from MedPAC in 2 ways. First, we ran separate analyses based on MDC where MedPAC pooled across diagnostic categories. Second, the data used by MedPAC is older and does not reflect the increasing complexity of patients treated in LTCHs.²³

Other government-funded studies examined Medicare payments, but not mortality, and found consistently higher episode payments for cases treated at LTCHs than those treated in other settings, although these studies do not adjust for selection bias due to unobservable characteristics.^{23,24} In contrast, we used an instrumental variable technique as a way to establish the causal effects of receiving care in an LTCH on patient outcomes. While there is ongoing debate in the clinical literature as to whether any observational study can establish causal relationships, studies demonstrate that instrumental variable techniques produce consistent estimates of treatment effects if valid instruments are used.²⁵ Our instrumental variables passed diagnostic tests related to exogeneity and relevance. However, no test can definitely determine whether all necessary assumptions for instrument validity have been fulfilled.

The variation in our findings across MDCs suggests different mechanisms may be at play in the provision of LTCH care. On one hand, LTCH care may improve patient outcomes by providing specialized care programs for medically complex and chronically critically ill patients over an extended inpatient period. Moreover, LTCHs may offer care from clinicians with

the enhanced expertise and experience obtained from treating a critical mass of such patients. On the other hand, LTCH care may negatively affect patient outcomes by introducing fragmentation and added transitions in care.

Policy makers are concerned over the rapid growth of LTCHs and uncertainty over the role of LTCHs in the treatment of Medicare beneficiaries. The Pathway for SGR Reform Act of 2013 imposes new LTCH criteria intended to limit the types of patients treated in LTCHs. Our findings show that LTCH care is beneficial for some groups of patients, particularly for patients with higher acuity. The results with respect to those patients who receive ≥ 3 days of ICU/CCU care support the criteria established by the Pathway for SGR Reform Act, whereas the findings for patients with multiple organ failure point to a group of patients who benefit from LTCH care but may not be covered under the new criteria.

There are a number of limitations to consider when reviewing the study findings. First, we were limited to outcomes that could be determined from medical claims and administrative data. For example, mortality captures length and not necessarily quality of life. Second, as treatment effects are assumed to be heterogeneous among study patients, the study's findings apply only to the subset of patients whose LTCH transfer decision would change as a result of changes in the instrumental variables. Third, some patients who died in the ACH may have died before transfer to an LTCH would have been feasible. To address this challenge, we excluded patients who died before the MS-DRG-specific geometric mean time to transfer to an LTCH, but no cutoff

will precisely identify the subset of patients who died before an LTCH decision. Fourth, our definition of Medicare payments excludes payments to physicians, hospital outpatient departments, hospice and medical equipment providers. Finally, we are unable to account for do-not-resuscitate (DNR) orders. If patients' DNR status is correlated with our instrumental variables, our models may overestimate the magnitude of the LTCH effect on mortality.

While this study should inform future policy developments related to LTCHs, it also points to areas for future work. Research should examine the effects of LTCH care on other patient populations, conditions, and characteristics. Research is also needed to better understand the mechanisms behind the variation in mortality rates and spending for patients treated in LTCHs. Our understanding of the role of LTCHs in the continuum of care should be enhanced as clinical data become more available to assess differences in patients and outcomes across postacute care settings.

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