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Impact of Oral Nutritional Supplementation on Hospital Outcomes

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Malnutrition is a serious and underappreciated problem among hospitalized patients. Malnourished patients face heightened risks of poor outcomes, including increased length of stay (LOS),[1-3] healthcare costs,[1,4] complication rates,[2,4-7] readmission rates,[8,9] and mortality.[2,10-12]

Estimates of malnutrition prevalence in the inpatient population range from 8% to 62%, depending on the location and the specific patient population considered.[13-17] Groups at highest risk include elderly as well as oncology and gastroenterology patients.[16] Despite evidence documenting the deleterious effects of malnutrition in the inpatient setting, studies suggest it is a common problem that often goes unrecognized and undertreated.[15,18]

A growing body of evidence suggests that oral nutrition supplements (ONS), which deliver both macronutrients and micronutrients for special medical purposes in addition to normal food, might improve outcomes among hospitalized patients. A variety of benefits have been found for ONS use, including reduced LOS,[3] inpatient episode cost,[3,19] complication rates,[19,20] depressive symptoms,[21] and readmission rates,[22,23] and improved lean body mass recovery.[24] However, previous studies suffer from limitations, including modest sample sizes, narrowly selected patient populations, and in observational studies, possible selection bias. Consequently, questions remain regarding the robustness and generalizability of existing findings and the size of gains and healthcare costs associated with ONS use in hospitalized patients.

This retrospective data analysis was conducted to assess the association and causal impacts of ONS on health outcomes for hospitalized patients, focusing on 3 key outcomes: LOS, episode cost, and probability of 30-day readmission.

Objectives: To assess the effect of inpatient oral nutritional supplement (ONS) use on length of stay, episode cost, and 30-day readmission probability.

Study Design: Eleven-year retrospective study (2000 to 2010).

Methods: Analyses were conducted using the Premier Perspectives Database, which contained information on 44.0 million adult inpatient episodes. Using a matched sample of ONS and non-ONS episodes for any inpatient diagnosis, instrumental variables regression analysis was performed to quantify the effect of ONS use on length of stay, episode cost, and probability of approximate 30-day readmission. For the readmission outcome, the matched sample was restricted to episodes where the patient was known to be at risk of readmission. The fraction of a hospital's episodes in a given quarter involving ONS was used as an instrumental variable.

Results: Within the database, 1.6% of 44.0 million adult inpatient episodes involved ONS use. Based on a matched sample of 1.2 million episodes, ONS patients had a shorter length of stay by 2.3 days (95% confidence interval [CI] – 2.42 to –2.16), from 10.9 to 8.6 days (21.0% decline), and decreased episode cost of $4734 (95% CI – $4754 to – $4714), from $21,950 to $17,216 (21.6% decline). Restricting the matched sample to the 862,960 episodes where patients were readmitted at some point, ONS patients had a reduced probability of early readmission (within 30 days) of 2.3 percentage points (95% CI – 0.027 to – 0.019), from 34.3% to 32.0% (6.7% decline).

Conclusions: Use of ONS decreases length of stay, episode cost, and 30-day readmission risk in the inpatient population.

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For author information and disclosures, see end of text.

METHODS

Setting, Subjects, and Data Sources

This analysis was conducted using the Premier Perspectives Database. This database contains diagnostic and billing information on 44.0 million adult inpatient episodes at 460 sites during the years 2000 to 2010. Premier estimates that these data cover 20% of all US inpatient episodes. The sample was restricted to adults 18 years or older and excluded terminal episodes and all

In this article
Take-Away Points / p122
www.ajmc.com
Full text and PDF
Web exclusive
eAppendix

Take-Away Points

Malnutrition is a serious but underappreciated problem among hospitalized patients. There is relatively little evidence evaluating the large-scale effectiveness of therapeutic interventions against malnutrition. We conducted an instrumental variables analysis to determine the effect of oral nutritional supplement use in the inpatient setting.

- Use of oral nutrition supplements decreased length of stay, episode cost, and probability of 30-day readmission.
- By increasing oral nutrition supplement use, hospitals can improve hospitalization outcomes and decrease healthcare spending.

episodes involving tube feeding, leaving only oral feeding for examination. All monetary figures were reported in 2010 dollars and inflation-adjusted based on the Bureau of Labor Statistics medical Consumer Price Index (http://www.bls.gov/cpi/#tables).

Measures

The study's 3 key outcome variables were LOS, episode cost, and probability of 30-day readmission. Length of stay was defined as the number of days of direct patient care (minimum 1 day) from admission to discharge. Episode cost was defined as the actual costs to treat the patient during the hospitalization. Thirty-day readmission probability was defined as a return hospitalization for any diagnosis. For patient confidentiality purposes, the Premier database only contains the month and year of an inpatient episode. Therefore, the 30-day readmission window was calculated by identifying admissions later the same month or during the following month. Given that there are no *International Classification of Diseases, Ninth Revision* or Current Procedural Terminology codes that identify ONS use, ONS was defined as a "complete nutritional supplement, oral," as indicated by the Premier data, and coded as a binary variable, indicating any ONS used during the inpatient episode.

Statistical Analysis

Naïve ordinary least squares (OLS) regression analyses were performed on the full matched sample. Analyses controlled for a variety of patient, episode, and provider characteristics. Demographic covariates included age, age squared, insurance type, marital status, race, and sex. Comorbidity covariates included all components of the Charlson Comorbidity Index.[25,26] Health history covariates included whether the patient had been admitted to any Premier network hospital in the previous 6 months, and whether the patient was admitted from the emergency department, by physician referral, or by inter-facility transfer. Hospital-specific covariates included number of beds, urban location, whether the site was a teaching hospital, and region (Northeast, Midwest, West, or South as defined by US Census data). Time trends were controlled for using year and quarter dummies.

Treatment is assigned randomly in clinical trials to avoid confounding; however, there is potential for selection bias in observational research from unobserved factors that may influence study outcomes.[27,28] Because it is likely to be administered to individuals who are less healthy, ONS use could be spuriously associated with increased LOS. Additionally, only certain patient health-related risk factors were directly observable with available data. Therefore, further methods were used to remove these sources of potential selection bias: propensity score matching and instrumental variables analysis.

Propensity Score Matching. To diminish the potential for confounding due to differences in observed personal characteristics and to identify nutritionally at-risk patients, propensity score matching[29] was used to match ONS episodes to similar non-ONS episodes. The probability of receiving ONS was estimated using a logistic regression of ONS based on the covariates noted above. After removing all episodes involving children (<18 years) and tube feeding, each ONS episode was matched to its nearest non-ONS episode neighbor.

Instrumental Variables Analysis. Instrumental variable analysis was used to specifically address potential bias due to nonrandomized treatment selection, which could not be addressed with propensity matching alone. Instrumental variables can remove the effect of selection bias and identify the causal effect of a treatment on outcomes.[30-32] Using this method requires an instrument that correlates with the treatment of interest but does not affect the outcome, except through its influence on the likelihood of receiving treatment.

For this analysis, the selected instrument was the fraction of episodes involving any ONS use in a given hospital in a given quarter. By looking at changes in ONS use based on a hospital's inclination to prescribe it, rather than underlying patient characteristics, the unbiased identification of the effect of ONS was made feasible. Since instrumental variable properties are best understood in linear settings,[33] this instrument was applied to linear models of the 3 outcomes. Several tests of the instrument's validity were performed.

To control further for unobserved patient heterogeneity, the model included fixed effects for groups based on how long patient data remained observable prior to loss to follow-up. These fixed-effects "follow-up" groups were no patient follow-up data; 1 day through 1 year of follow-up; 1 to 2 years of follow-up; 2 to 3 years of follow-up; and more than 3 years of follow-up. Because life expectancy cannot generally be observed in the Premier database (except when individuals die in a Premier network hospital), follow-up duration served as

Table 1. Descriptive Statistics by ONS Use, Full and Matched Samples[a]

Characteristics	All ONS Episodes (N = 724,027)	All Non-ONS Episodes (N = 43,244,540)	*P*	Matched ONS Episodes (n = 580,044)	Matched Non-ONS Episodes (n = 580,044)	*P*
Age, y	68.4	56.7	<.0001	67.7	68.3	<.0001
Female	54.0%	61.0%	<.0001	54.7%	54.3%	.0001
Race						
Black	12.6%	12.8%	<.0001	12.5%	12.4%	.4683
Hispanic	6.4%	6.1%	<.0001	6.6%	6.4%	.0037
White	68.4%	63.6%	<.0001	68.3%	68.7%	<.0001
Admitted past 6 mo	42.2%	25.6%	<.0001	41.5%	41.5%	.5589
Admitted from ED	58.2%	47.0%	<.0001	59.6%	60.7%	<.0001
Readmitted within 30 d	25.1%	15.6%	<.0001	24.1%	25.4%	<.0001
Length of stay, d	12.5	4.8	<.0001	11.2	8.3	<.0001
Discharge to home	33.3%	70.0%	<.0001	36.8%	36.8%	1.0000
Charlson Comorbidity Index score	3.5	2.1	<.0001	3.5	3.5	<.0001
Selected Charlson Index comorbidities						
Myocardial infarction	10.8%	8.0%	<.0001	10.7%	10.8%	.7598
Congestive heart failure	27.5%	13.9%	<.0001	27.2%	26.7%	<.0001
Peripheral vascular disease	0.2%	6.1%	<.0001	9.8%	10.0%	.0024
Cerebrovascular disease	14.3%	6.9%	<.0001	12.3%	12.2%	.1556
Chronic pulmonary disease	31.0%	19.8%	<.0001	31.0%	31.1%	.4913
Diabetes without complications	22.8%	18.6%	<.0001	22.8%	22.8%	.3676
Diabetes with complications	5.1%	3.5%	<.0001	5.1%	5.4%	.0001
Renal disease	13.9%	8.6%	<.0001	13.8%	13.9%	.0764
Cancer	13.8%	7.2%	<.0001	13.6%	13.4%	.0006
Metastatic carcinoma	6.9%	3.1%	<.0001	6.8%	6.7%	.0193

ED indicates emergency department; ONS, oral nutritional supplement.
[a]Matched episodes excluded tube feeding. Definitions of "admitted past 6 months" and "readmitted within 30 d" were approximate as the underlying data represent dates as only month and year. A more extensive list of descriptive statistics is given in Table A1 in the eAppendix.

a proxy for underlying health status. Observed follow-up using hospital-based data may be a preferable measure of overall patient frailty, because the diagnostic codes present in a single episode (vs multiple follow-up episodes) are unlikely to reflect the full range of patient comorbidities.

Additional Modeling of Readmissions. For the readmission outcome, the matched sample was restricted to episodes where the patient was known to be at risk of readmission following discharge. If patients did not die following hospitalization, it could be assumed ONS had 2 potential benefits: it prevented readmissions by making people healthy, or it delayed readmissions among those eventually readmitted. Because the Premier data did not distinguish between patients not readmitted due to recovery and those not readmitted due to death, the current study could only measure the effect of delayed readmission (by calculating the change in 30-day readmission probability among patients eventually readmitted). This approach also provided a conservative estimate of the total impact of ONS on readmission.

Return on Investment Calculations. Next, estimates for the effect of ONS on LOS, episode cost, and readmission probability were used to calculate a return on investment (ROI) for ONS use, using the following formula:

$$\text{ROI} = \frac{\text{savings generated through ONS use} - \text{amount spent on ONS}}{\text{amount spent on ONS}}$$

The above formula yields the "episode cost" ROI of ONS use through reduced episode cost. Savings generated from ONS use were defined as the average reduction in episode cost due to ONS use. The amount spent on ONS was the average episode cost of ONS use. For readmission ROI, the average

Table 2. Mean Characteristics of Matched ONS Sample Subgroups

Episode Characteristic	Mean by Group					
	All (N = 1,160,088)	No Follow-up (n = 297,128)	Follow-up 1 d to <1 y (n = 566,682)	Follow-up 1 y to <2 y (n = 104,141)	Follow-up 2 y to <3 y (n = 64,813)	Follow-up ≥3 y (n = 127,324)
Age, y	68.0	67.1	68.8	68.9	68.3	65.5
Female	54.5%	53.3%	53.6%	56.4%	57.7%	58.3%
Admitted past 6 mo	41.5%	33.2%	43.5%	49.2%	46.7%	42.4%
Admitted from ED	60.1%	58.8%	60.1%	63.9%	63.2%	58.7%
Discharged to home	36.8%	35.8%	33.2%	40.3%	42.5%	49.1%
Readmitted within 30 d	24.7%	0.0%	36.2%	29.5%	27.8%	25.6%
Length of stay, d	9.7	10.0	9.9	9.1	9.1	9.0
Episode cost	$18,981	$20,414	$19,381	$16,763	$16,704	$16,825
Charlson Comorbidity Index score	3.5	3.5	3.8	3.3	3.0	2.5

ED indicates emergency department; ONS, oral nutritional supplements.

episode cost among the readmitted population was multiplied by the reduction in the probability of readmission to calculate the savings generated through ONS use. The amount spent on ONS was defined as for the episode cost ROI.

Computation. Analyses were performed using Stata version 11 (StataCorp LP, College Station, Texas). A 2-sided *P* value of .05 or less was considered statistically significant. A detailed summary of additional testing and sensitivity analyses conducted to validate study results can be found in the **eAppendix** (available at **www.ajmc.com**).

RESULTS

From 46.1 million inpatient episodes and 810,589 episodes involving ONS use, we excluded 306,528 tube-feeding episodes, 1,798,907 involving patients under age 18 years, 112 with incomplete data, and 19,817 terminal episodes to obtain a sample of 44.0 million episodes and 724,027 ONS episodes. The overall rate of ONS use in adult inpatient episodes was 1.6%. Each adult ONS episode was matched to an adult non-ONS episode, to obtain a matched sample of 1,160,088 episodes.

Mean characteristics of ONS episodes, all non-ONS episodes, and matched non-ONS episodes are reported in **Table 1**. Compared with general non-ONS inpatient episodes, individuals receiving ONS were older (age 68.4 vs 56.7 years) and less healthy on various dimensions; and 42.2% of ONS episodes were preceded by an admission in the prior 6 months, compared with only 25.6% for non-ONS episodes. The average LOS for an ONS episode was 12.5 days compared with 4.8 days for non-ONS episodes.

Table 2 shows the characteristics of matched ONS sample subgroups by follow-up group. Patient ONS use was highly correlated with other health markers, including prior admission history, LOS, episode cost, and Charlson Comorbidity Index score.

Length of Stay

Ordinary least squares regression analysis performed on the full matched sample showed that ONS use was associated with a 2.9-day (95% confidence interval [CI] 2.8-3.0 days), or 34.7%, increase in LOS, from 8.3 to 11.2 days. However, when instrumental variables regression analysis was used to account for selection bias, ONS lowered LOS by 2.3 days (95% CI −2.4 to −2.2 days), or 21.0%, from 10.9 to 8.6 days (**Table 3**, columns 1 and 2).

Next, to determine whether the effect of ONS differed depending on the underlying health status of the treated individual, the instrumental variables regression analysis was repeated on matched sample subgroups, sorted by duration of observed follow-up. For this comparison, all episodes with no observed follow-up were dropped. Once the matched sample was restricted in this way (Table 3, columns 3-6), episodes with longer follow-up duration were successively dropped to create an increasingly sick sample moving from column 3 (patients with at least 1 day of follow-up) to column 6 (patients with 1 day to 1 year of follow-up). When the data were grouped in this way, it became apparent that ONS had the greatest LOS benefit for the sickest group (−22.8%) and a smaller, but still significant, benefit for the healthiest group (−16.3%).

Episode Cost

Ordinary least squares regression analysis showed that ONS use was associated with an increased episode cost of $7598 (95% CI $7579-$7617), or 50.7%, from $14,998 to $22,596

Table 3. Effect of ONS Use on Length of Stay[a]

	Regression Specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Subset of Matched Sample Analyzed	**All**	**All**	**Follow-up at least 1 d**	**Follow-up 1 d to 3 y**	**Follow-up 1 d to 2 y**	**Follow-up 1 d to 1 y**
Model	OLS	IV	IV	IV	IV	IV
Effect of any ONS use on LOS, d (SE)	2.879[b] (0.0432)	−2.291[b] (0.0657)	−1.714[b] (0.0721)	−2.299[b] (0.0843)	−2.407[b] (0.0892)	−2.585[b] (0.103)
Predicted LOS without ONS, d	8.30	10.88	10.5	10.93	11.07	11.32
Predicted LOS with ONS, d	11.18	8.59	8.79	8.63	8.66	8.74
Change due to ONS use	34.7%	−21.0%	−16.3%	−21.0%	−21.8%	−22.8%
Observations, n	1,160,088	1,160,088	862,960	735,636	670,823	566,682

IV indicates instrumental variable; LOS, length of stay; OLS, ordinary least squares; ONS, oral nutritional supplement; SE, standard error.
[a]Regression results were from a sample of ONS episodes matched 1:1 to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Standard errors took into account repeated observations of the same individual.
[b]Significant at the 1% level.

(Table 4, column 1). However, when the instrumental variables method was applied to the full matched sample (Table 4, column 2), ONS use decreased episode cost by $4734 (95% CI –$4754 to –$4714), or 21.6%, from $21,950 to $17,216. When the matched samples were grouped in terms of duration of known follow-up (Table 4, columns 3-6), a clear pattern was observed, with the largest ONS benefit going to the sickest individuals. Episode cost savings ranged from 17.9% to 24.0% for the healthiest to the sickest subgroups, respectively.

Readmission

In the known follow-up subsample, naïve OLS regressions showed that ONS use was associated with a 0.3 percentage point (95% CI –0.005 to –0.001), or 0.9%, decrease in readmission probability, from 33.4% to 33.1% (Table 5, column 1). Instrumental variables regression results demonstrated that ONS use led to a 2.3 percentage point (95% CI −0.027 to −0.019), or 6.7%, decrease in the probability of readmission among episodes with any follow-up, from 34.3% to 32.0% (Table 5, column 2). Assuming conservatively that ONS provided no benefit to patients never readmitted and served only to delay readmissions among those who were eventually readmitted, this finding implied that ONS decreased the probability of readmission in the full matched sample by at least 6.9% (measured as a 0.0231 reduction in readmission probability multiplied by the 74% of the matched sample eventually readmitted, divided by a baseline 30-day readmission rate of 24.7% in the matched sample). Grouping the subsample with known follow-up by underlying health status (Table 5, columns 2-5) again shows a clear pattern of the largest benefit of ONS use going to the sickest individuals (14.1%).

Return on Investment

Use of ONS cost an average of $88.26 per episode. This cost included the cost of ONS and associated labor and administrative expenses, based on hospital reporting. When held against the estimate (Table 4, Column 2) that ONS use generates $4734 in savings per episode, this amounted to an ROI of $52.63 in net savings for every dollar spent on ONS in terms of reduced episode cost.

To calculate readmission ROI, it was assumed that hospital sites could not distinguish between individuals who would eventually be readmitted and those who would not, and therefore had to administer ONS to all matched sample patients. As noted previously, study estimates indicated that ONS decreased readmission probability by 0.0231 for the 74% of the matched sample eventually readmitted. This conservatively assumed no benefit from readmission prevention for the other 26%. This effect was then multiplied by $18,478 (the average population episode cost for inpatient readmission), resulting in an estimated $314.13 in savings per episode due to ONS use. This translated into an ROI of at least $2.56 in net savings due to averted 30-day readmissions for every dollar spent on ONS in the matched sample.

DISCUSSION

This study found that ONS use in hospitalized patients led to substantial reductions in LOS, episode cost, and 30-day readmissions. Specifically, ONS use resulted in a 2.3-day (21.0%) LOS decrease, $4734 (21.6%) in decreased episode costs, and a 6.7% decrease in 30-day readmissions among patients eventually readmitted. Conservatively assuming no benefit to those never readmitted, these outcomes translated

Table 4. Effect of ONS Use on Episode Cost[a]

	Regression Specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Subset of Matched Sample Analyzed	**All**	**All**	**Follow-up at least 1 d**	**Follow-up 1 d to 3 y**	**Follow-up 1 d to 2 y**	**Follow-up 1 d to 1 y**
Model	OLS	IV	IV	IV	IV	IV
Effect of any ONS use on episode cost (SE)	$7598[b] ($9.70)	−$4734[b] ($10.07)	−$3694[b] ($10.47)	−$4473[b] ($11.69)	−$4873[b] ($12.5)	−$5519[b] ($14.25)
Predicted episode cost without ONS	$14,998	$21,950	$20,664	$21,522	$22,028	$22,950
Predicted episode cost with ONS	$22,596	$17,216	$16,969	$17,049	$17,155	$17,431
Change due to ONS use	50.7%	−21.6%	−17.88%	−20.78%	−22.12%	−24.0%
Observations, n	1,160,088	1,160,088	862,960	735,636	670,823	566,682

IV indicates instrumental variables; OLS, ordinary least squares; ONS, oral nutritional supplement; SE, standard error.
[a]Regression results were from a sample of ONS episodes matched 1:1 to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. The dependent variable in the regressions was log of episode cost. Costs are in 2010 dollars. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Predicted episode costs used Duan's smearing estimator. Standard errors took into account repeated observations of the same individual.
[b]Significant at the 1% level.

to a minimum 6.9% decrease in readmissions among the full matched sample of all ONS episodes and similar non-ONS episodes. The study of 30-day readmissions is particularly relevant, given new Medicare rules that may make hospitals liable for some readmissions within 30 days.[34-40]

These gains, it is important to note, are consistent with results from previous randomized controlled trials. In a study of general inpatients, Somanchi and colleagues found that early nutritional intervention reduced LOS by 1.93 days (P = .003), and in a severely malnourished subpopulation, reduced LOS by 3.2 days (P = .052).[3] In a UK-based study, Lawson and colleagues found that ONS was associated with a 6% reduction in episode cost.[19] Somanchi et al found a $1514 episode cost decrease among severely malnourished patients.[3] This cost reduction was lower than that observed in the current study. However, Somanchi et al calculated cost savings as number of days of reduced LOS multiplied by average cost of additional days. This approach did not take into account that ONS use might make the inpatient stay less resource intensive, not just shorter.

In a trial with malnourished patients, Norman and colleagues found that ONS use decreased 3-month readmissions from 48% to 26%.[23] Likewise, Gariballa and colleagues found that ONS use led to a 28% reduction in 6-month readmissions, from 40% to 29% (adjusted hazard ratio 0.68 [95% CI = 0.49-0.94]).[22] However, in both of these randomized controlled trials, ONS use was sustained postdischarge. For the current study, it was not possible to determine whether patients continued ONS after leaving the hospital.

Because ONS is inexpensive to provide, the sizable savings generated make it a cost-effective therapy. From the healthcare perspective, for every dollar spent on ONS, the ROI was $52.63 in immediate net episode cost savings and $2.56 in net savings from avoided 30-day readmissions. The 1:1 matched sample estimates imply that doubling ONS use by targeting patients similar to current ONS users is likely to produce financial returns to hospitals and improve patient outcomes. Sensitivity analyses suggest that further increases beyond doubling may continue to generate positive results, but more research is needed on this point.

The current study has 2 key advantages over previous research. First, it used a large database to estimate the effect of ONS based on real-world data. With 44 million adult inpatient episodes, these data were relevant and broadly representative. Second, econometric methods were used to enable causal inference regarding the impact of ONS on patient outcomes. By applying propensity score matching and instrumental variables, potential bias due to nonrandom selection into ONS treatment was mitigated. This made it possible to estimate causal impact of ONS use on LOS, episode cost, and readmission probability.

However, the Premier Perspectives data did have limitations. The lack of detailed patient health information, such as laboratory test results and patient health status assessment, led to a selection challenge whereby patients receiving ONS were presumably sicker on a variety of dimensions not fully observable in the data. This limitation was addressed using propensity score matching and instrumental variables analysis. In addition, the fact that it was not possible to distinguish between avoided readmissions due to recovery, death, or transfer to a non-Premier hospital meant that analyses of

Table 5. Effect of ONS Use on 30-Day Readmission[a]

	Regression Specification				
	(1)	(2)	(3)	(4)	(5)
Subset of Matched Sample Analyzed	**Follow-up at least 1 d**	**Follow-up at least 1 d**	**Follow-up 1 d to 3 y**	**Follow-up 1 d to 2 y**	**Follow-up 1 d to 1 y**
Model	OLS	IV	IV	IV	IV
Effect of any ONS use on probability of readmission (SE)	−0.00310[b] (0.00103)	−0.0231[b] (0.00204)	−0.0475[b] (0.00225)	−0.0504[b] (0.00235)	−0.0550[b] (0.00254)
Predicted probability of readmission without ONS	0.334	0.343	0.369	0.377	0.391
Predicted probability of readmission with ONS	0.331	0.320	0.322	0.327	0.336
Change due to ONS use	−0.9%	−6.7%	−12.7%	−13.3%	−14.1%
Observations, n	862,960	862,960	735,636	670,823	566,682

IV indicates instrumental variables; OLS, ordinary least squares; ONS, oral nutritional supplements; SE, standard error.
[a]The 30-day readmission window was approximate as only the month and year were observed in the data. Regression results were from a sample of ONS episodes matched 1:1 to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Standard errors took into account repeated observations of the same individual.
[b]Significant at the 1% level.

the effect of ONS on readmission had to be confined to a subsample of episodes with known follow-up. Therefore, the benefit of ONS could only be quantified based on delayed, rather than prevented, readmission. The Premier data set did not provide data on ONS use following discharge. Lastly, although we performed multiple instrument validity tests, more comprehensive tests could be performed with hospital-specific quality measures such as report cards. In the future, researchers with access to more comprehensive data may be able to gain additional insight on this issue.

Using the instrumental variables method, this study found that the use of ONS led to statistically significant decreases in inpatient LOS, episode cost, and readmission. Given the high prevalence of malnutrition among inpatient populations, these results suggest that ONS use could help improve outcomes at relatively low cost to the healthcare system. Today, hospitals are facing pressures to find low-cost, highly effective therapy while maintaining quality of care. By increasing ONS use, hospitals can improve hospitalization outcomes and decrease healthcare spending.

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■ **eAppendix.** Additional Technical Details on the Definition of Oral Nutritional Supplement Use, Definition of Covariates, Episode Cost Predictions, Readmissions Modeling, Instrument Validity Tests, and Sensitivity Analysis

Definition of ONS Use

Oral nutritional supplement (ONS) use was defined as a binary indicator that any amount of ONS was used during an inpatient episode. There are no *International Classification of Diseases, Ninth Revision (ICD-9)* or Current Procedural Terminology (CPT) codes that identify ONS use. However, the Premier Perspectives data are derived from hospital billing records, and therefore contain not only diagnoses and procedures but also a detailed list of products provided during the inpatient stay, to be used for billing purposes. Use of ONS was flagged for any episode indicating the provision of "complete nutritional supplement, oral," as classified by the Premier data. The list of products corresponding to the Premier definition of ONS was manually checked; to ensure that these products were actually used orally, we dropped all episodes involving tube feeding. (To identify episodes involving tube feeding, we used CPT codes 43246, 43653, 43750, 43832, 44372, 44373, 74350, 43246, 49440, 49441, 43241, and 43752, and *ICD-9* procedure codes 43.1, 43.11, 43.19, 44.32, V44.1, 44.4, and 46.432.)

Definition of Specific Covariates

Marital status was coded as a dummy indicating whether the patient was married at the time of the episode. Race was coded as dummies indicating black, white, or Hispanic race. Insurance status was coded as dummies indicating whether the payer was Medicare, Medicaid, or managed care.

Charlson Comorbidity Index components were acute myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease, peptic ulcer disease, mild liver disease, diabetes without complications, diabetes with complications, paraplegia and hemiplegia, renal disease, cancer, moderate or severe liver disease, metastatic carcinoma, and HIV/AIDS. **Table A1** presents descriptive statistics by ONS use.

Episode Cost Predictions

To estimate the effect of ONS on episode cost, the natural logarithm of episode cost on ONS use and covariates was regressed using the instrumental variables method. To reduce the influence of outliers, the log of cost was applied as the dependent variable. Duan's smearing estimator was used to translate the predicted values back to dollars.[1]

Readmissions Modeling

After patients were discharged from the hospital, 1 of 4 outcomes was possible: (1) The individual might become healthy, in which case they would not return to the hospital. (2) The individual might be readmitted within the Premier hospital network. (3) The individual might be readmitted out of the Premier hospital network. (4) The individual might die. The **Figure** illustrates the conceptual relationship between ONS and readmission, as it is measured in the Premier database.

Use of ONS has 2 potential effects on 30-day readmission: it may prevent readmission by shifting individuals from the readmitted state to the healthy state (effect 1), or it may delay readmission by shifting readmitted individuals from the state of being readmitted within 30 days to the state of being readmitted past 30 days. Because the Premier data did not distinguish between individuals not readmitted due to recovery and those not readmitted due to death, this analysis by necessity focuses on delays in readmission (effect 2).

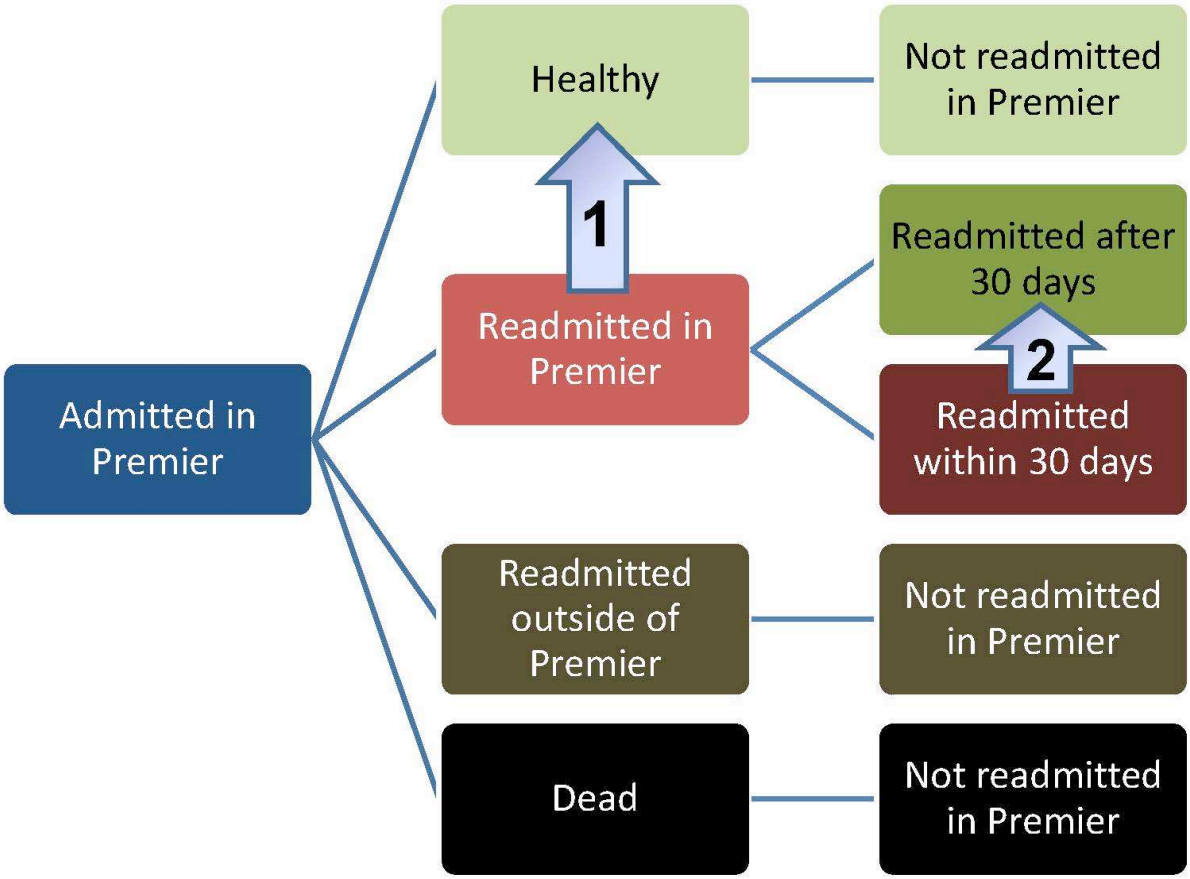

Figure 1. Effects of ONS Use on Readmission

ONS indicates oral nutritional supplements

Instrument Validity Tests

Methods

Because the causal interpretation of our estimates rests on the appropriateness of our instrumental variables method, we performed several tests of the validity of our instrument (the fraction of episodes in a given hospital in a given quarter involving ONS use). We measured the F statistics of our first-stage regressions, as this was a good guide to the strength of our instrument in predicting our endogenous variable (that is, ONS use).[2,3]

In contrast, the second requirement of a valid instrument—that it be uncorrelated with unobserved variables that influence the outcome, commonly called the "exclusion restriction"—

could not be tested directly. Although by design our instrument removed any personal characteristics from the estimation of the effect of ONS, it is possible that our instrument could have been correlated with unobserved provider-level characteristics that influenced outcomes, such as hospital quality. To test whether this might have been the case, we performed 2 tests to address the validity of the exclusion restriction.

The first test involved measuring whether the instrument was correlated with hospital quality, as measured by the adoption of new technologies. We regressed our instrument on all provider characteristics (as listed in the above covariates), a time trend, and a set of dummies measuring the adoption of new, high-technology procedures. We created flags identifying whether a provider had billed using CPT codes for any of the following procedures: angioplasty stents (35470, 35471, 35472, 35473, 35474, 35475, 35476, 37205, and 37206), cardiac catheterization (93451-93533), endovascular graft (33880, 3388, 75956, and 75957), image-guided surgery (61781, 61782, and 77011), implantable neurostimulator (0171T and 0172T), implantable cardioverter (93282-93284, 93289, 93296, and 93295), infused bone graft (27759), intraoperative magnetic resonance imaging (70557-70559), Kinetra (61863, 61864, 61874, 61868, 61880, 61885, 61886, 95970, 95978, and 95979), minimally invasive surgery (44180, 43644, 449770, and 45397), and thrombolytics (37201 and 75896). We performed a second regression that also included the average of all episode characteristics from the covariates (excluding the follow-up group fixed effects). These regressions tested whether hospitals using ONS more intensively also systematically adopt new technologies earlier; if true, this might create problems by creating a correlation between high ONS use and better patient care on dimensions unrelated to ONS use.

As a second test of the validity of the exclusion restriction, we compared episode characteristics across high and low ONS propensity hospitals. The purpose of this test was to investigate the extent to which high ONS propensity hospitals had healthier patients or more favorable outcomes to begin with. Because we were concerned with the underlying characteristics of the hospital and not merely those (relatively uncommon) episodes in which a decision to provide ONS was made, we calculated a hospital's mean episode characteristics using all episodes within the given hospital, rather than just those selected into the matched sample.

To do this, we sorted all hospitals in the data by the fraction of their episodes that involved ONS use, which enabled us to define high ONS propensity and low ONS propensity hospitals. We used 2 alternative definitions of high and low ONS propensity. According to the first definition, hospitals with ONS use below the 5th percentile were considered low ONS propensity hospitals, while hospitals with ONS use above the 95th percentile were considered high ONS propensity hospitals. According to the second definition, we specified low ONS propensity as below the 50th percentile and high ONS propensity as above the 50th percentile. Mean episode characteristics were calculated and compared using 2-tailed *t* tests across the low ONS propensity and the high ONS propensity hospitals.

Results

To test for relevance, we predicted ONS use using all covariates in our model as well as our instrument. (This is known as the "first stage" regression.) A typical rule of thumb suggests that an F statistic over 10 largely eliminates bias created by an insufficiently relevant instrument.[3] Our F statistic was 6273.10 in the full matched sample and 2416.54 in the subsample with the smallest F statistic; thus relevance was satisfied.

The exclusion restriction could not be directly tested (because the unobserved characteristics were indeed unobservable), but with some care, tests could be thought of that provided insight on whether the exclusion restriction was likely to be satisfied.

In our first test of the exclusion restriction, we advanced the possible concern that ONS-using hospitals also systematically adopt new technologies more rapidly and thus produce better outcomes for patients. If true, the ONS use instrument would be correlated with provider quality. We tested this hypothesis directly using 11 commonly cited cutting-edge technologies.[4,5] The question is whether ONS use is systematically positively correlated with technology adoption. Of the 11 technologies considered, we found that 2 technologies were significantly positively predictive of provider-level ONS use, 1 to 3 technologies were significantly negatively predictive of provider-level ONS use (depending on whether we used the short or long list of provider-level covariates), and the rest had no statistically significant relationship with provider-level ONS use. In other words, there is no clear pattern between high-technology adoption and ONS use at the provider level.

In our second test of the exclusion restriction, we compared the episode characteristics across low and high ONS propensity hospitals, as presented in **Table A2**. We identified 162 hospitals with ONS use below the 5th percentile and 23 hospitals with ONS use above the 95th percentile, containing 12,885,871 and 2,044,231 episodes, respectively. Similarly, we identified 230 hospitals with ONS use below the 50th percentile and 230 hospitals with ONS use above the 50th percentile, containing 21,587,029 and 24,506,535 episodes, respectively.

Differences between the low and high ONS propensity hospitals were typically small, yet given the enormous sample size, nearly all differences were highly statistically significant. Some comorbidities, such as peripheral vascular disease and cerebrovascular disease, were more prevalent in the high ONS propensity hospitals (6.2% vs 4.9% in the 95/5 sample [P <.0001] and 5.3% vs 5.0% in the 50/50 sample [P <.0001] for peripheral vascular disease; 6.3% vs 5.7% in the 95/5 sample [P <.0001] and 6.0% vs 5.9% in the 50/50 sample [P < .0001] for cerebrovascular disease). Other comorbidities, such as dementia and cancer, were more prevalent in the low ONS propensity hospitals (2.1% vs 2.3% in the 95/5 sample [P <.0001] and 2.1% vs 2.2% in the 50/50 sample [P <.0001] for dementia; 6.1% vs 6.5% in the 95/5 sample [P <.0001] and 6.2% vs 6.4% in the 50/50 sample [P <.0001] for cancer). The average Charlson Comorbidity Index score was 1.8 in both high and low ONS propensity hospitals, regardless of the percentile cutoffs used to define the hospital groups. To the extent that unobserved health status may be correlated with observed health status, this suggests that the underlying patient health status at the high and low ONS propensity hospitals is quite similar. Therefore, the results of this test support the validity of the instrument used in the study analyses.

Of course, these validity tests could not definitively prove the validity of our instrumental variables approach, as the exclusion restriction was fundamentally untestable. Nevertheless, given the variety of tests used and the lack of evidence of a positive correlation between hospital quality and ONS use, we find the results persuasive.

Sensitivity Analysis

Methods

In our baseline analysis, we artificially restricted the size of the matched sample to 1 non-ONS episode for every ONS episode. Our results thus showed the effect of ONS in a population of actual ONS episodes and an equal number of similar non-ONS episodes. To gain a sense of the

size of the ONS-eligible population and to understand how the results would vary if the matching were done more or less restrictively, we performed a sensitivity analysis in which we allowed as matches all non-ONS episodes for which the propensity to receive ONS was within a given tolerance of the associated ONS episode.

Using the same controls and stratification as in the 1-to-1 matching, we performed matches whereby each ONS episode was matched to many non-ONS episodes. We began by calculating the differences in propensity scores between each ONS episode and its associated non-ONS episode in the 1-to-1 matched sample. Intuitively, this summarizes the distribution of match quality in the baseline sample. We can construct "one-to-many" matching in a variety of ways, using alternative criteria for match quality. For example, insisting upon high match quality will reduce the number of matches, and vice versa. Specifically, we used the difference in propensity scores observed at the 25th and 95th percentiles of the match quality distributions. All non-ONS episodes whose propensity scores differed by less than this amount were matched to their corresponding ONS episode matches. The 25th percentile sample reflected a more closely matched sample than the base case analysis, while the 95th percentile sample was less closely matched. We hypothesized that ONS effects would be bigger for the more closely matched samples.

Results

We created 2 alternative matched samples by allowing any non-ONS episode to be matched to a given ONS episode if the difference in propensity score between the ONS episode and the non-ONS episode was less than a certain tolerance. (We then eliminated duplicate non-ONS episodes.) As the tolerance, we selected the 25th and 95th percentile propensity score differences in the 1-to-1 (base case) matched sample. The results of the sensitivity analysis are presented in **Table A3** (length of stay), **Table A4** (episode cost), and **Table A5** (readmission). In comparison to our base case matched sample of 1,160,088 episodes, the 25th percentile sample contained 792,280 episodes, and the 95th percentile sample contained 7,604,616 episodes.

Looking at the length of stay results (Table A3), we can see that ONS use led to a larger decrease in length of stay in the closely matched 25th percentile sample (−3.83 days; 95% confidence interval [CI] −4.03, −3.64), and a smaller, though still statistically significant, decrease in length of stay in the 95th percentile sample (−0.89 days; 95% CI −0.96, −0.82). From Table A3 it is

also clear that the 25th percentile sample episodes involve sicker individuals, as the predicted length of stay was considerably longer in this group (12.5 days without ONS, 8.7 days with ONS) than in the 95th percentile sample (7.1 days without ONS, 6.3 days with ONS).

Examining the episode cost results (Table A4), we saw a similar pattern. ONS use led to a larger decrease in episode cost in the 25th percentile sample (−$12,858; 95% CI −$12,818 to −$12,896) and a smaller, though still statistically significant, decrease in episode cost in the 95th percentile sample (−$3259; 95% CI −$3262 to −$3254). Again it is clear that the 25th percentile sample contains sicker individuals, as the average episode cost was considerably larger in this group ($31,759 without ONS, $18,901 with ONS) than in the 95th percentile sample ($14,114 without ONS, $10,855 with ONS).

Finally, the readmission results are presented in Table A5. In this case we did not see a monotonic relationship with the largest benefits of ONS in the more closely matched 25th percentile sample. The change in the probability of readmission among the subset of the sample known to be at risk of readmission (because they had at least 1 episode of follow-up) in the 25th percentile sample was not statistically significant from zero. In the much larger 95th percentile sample, however, there was a small but statistically significant reduction in probability of readmission (−0.009; 95% CI −0.013 to −0.005).

Return on Investment to Hospital Through Avoided Medicare Penalties

Methods

We estimated a return on investment (ROI) to the hospital based on the readmission effects. Starting in October 2012, Medicare was expected to institute penalties for excessive readmissions among patients with acute myocardial infarction, congestive heart failure, or pneumonia diagnoses.[6-12] If a hospital's risk-adjusted rate of readmissions for these patients is considered excessive, Medicare will deny reimbursement for the excessive readmissions, up to a certain cap.[6-12] For the hospital ROI, we calculated the penalties that a hospital would avoid if ONS were administered to all the matched non-ONS episode patients. Due to the absence of detailed data used by Medicare in its algorithm, we approximated this ROI by assuming the hospital had reached an excessive level of readmissions, but had not yet reached the cap.

Specifically, we restricted the sample to the Medicare population with a primary diagnosis of 1 of the 3 affected conditions. (For acute myocardial infarction, we used

International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] codes 41001, 41051, 41011, 41061, 41021, 41071, 41031, 41081, 41041, and 41091. For congestive heart failure, we used *ICD-9-CM* codes 39891, 40201, 40211, 40291, 40401, 40403, 40411, 40413, 40491, 40493, 4254, and 4255. For pneumonia, we used *ICD-9-CM* codes 480, 481, 482, 483, 484, 485, 486, and 487.) We then multiplied the decrease in the probability of 30-day readmission from switching the non-ONS episodes to ONS episodes by the actual cost of readmissions for those episodes. We conservatively assumed no savings were generated from averted readmissions, only from delays in readmissions past the 30-day window. However, we assumed that the provider could not tell who would eventually be readmitted, so that all non-ONS episodes were switched to ONS regardless of whether they could potentially generate a readmission delay or not. We summed the savings over all the non-ONS episodes at a given hospital over our sample period, and summed up the cost of the additional ONS across episodes to obtain an ROI for the hospital.

Results

Among the population of Medicare patients admitted for acute myocardial infarction, congestive heart failure, or pneumonia, we calculated that switching all non-ONS episodes to ONS episodes would generate an average ROI to the provider of $3.89 in net savings for every dollar spent on ONS (95% CI $3.61-$4.18). Because we assumed no benefit through readmissions preventions, only through delays, and because providers differed in the extent to which their patients were eventually readmitted, the ROI of additional ONS use varied by provider. The ROI also varied because we used the actual cost of the readmissions to calculate the savings, and the cost of readmissions varied by provider. The 10th percentile provider obtained an ROI of $1.79 in net savings for every dollar spent on ONS, while the 90th percentile provider obtained an ROI of $6.39 in net savings for every dollar spent on ONS.

Table A1. Descriptive Statistics by ONS Use, Full and Matched Samples[a]

Characteristics	All ONS Episodes (N = 724,027)	All Non-ONS Episodes (N = 43,244,540)	*P*	Matched ONS Episodes (n = 580,044)	Matched Non-ONS Episodes (n = 580,044)	*P*
Age, y	68.4	56.7	<.0001	67.7	68.3	<.0001
Female	54.0%	61.0%	<.0001	54.7%	54.3%	.0001
Race						
Black	12.6%	12.8%	<.0001	12.5%	12.4%	.4683
Hispanic	6.4%	6.1%	<.0001	6.6%	6.4%	.0037
White	68.4%	63.6%	<.0001	68.3%	68.7%	<.0001
Admitted past 6 mo	42.2%	25.6%	<.0001	41.47%	41.47%	.5589
Admitted from ED	58.2%	47.0%	<.0001	59.6%	60.7%	<.0001
Readmitted within 30 d	25.1%	15.6%	<.0001	24.1%	25.4%	<.0001
Length of stay, d	12.5	4.8	<.0001	11.2	8.3	<.0001
Discharged to home	33.3%	70.0%	<.0001	36.8%	36.8%	>.9999
Charlson Comorbidity Index score	3.5	2.1	<.0001	3.5	3.5	<.0001
Charlson Index comorbidities						
Myocardial infarction	10.8%	8.0%	<.0001	10.7%	10.8%	.7598
Congestive heart failure	27.5%	13.9%	<.0001	27.2%	26.7%	<.0001
Peripheral vascular disease	0.2%	6.1%	<.0001	9.8%	10.0%	.0024
Cerebrovascular disease	14.3%	6.9%	<.0001	12.3%	12.2%	.1556
Dementia	6.7%	2.5%	<.0001	6.5%	6.7%	.5832
Chronic pulmonary disease	31.0%	19.8%	<.0001	31.0%	31.1%	.4913
Connective tissue and rheumatic disease	2.9%	2.2%	<.0001	3.0%	3.0%	.8654
Peptic ulcer disease	2.8%	1.5%	<.0001	2.5%	2.5%	.8101
Mild liver disease	4.6%	2.9%	<.0001	4.8%	4.6%	<.0001

Diabetes without complications	22.8%	18.6%	<.0001	22.8%	22.8%	.3676
Diabetes with complications	5.1%	3.5%	<.0001	5.1%	5.4%	.0001
Paraplegia and hemiplegia	2.8%	1.5%	<.0001	2.5%	2.5%	.8101
Renal disease	13.9%	8.6%	<.0001	13.8%	13.9%	.0764
Cancer	13.8%	7.2%	<.0001	13.6%	13.4%	.0006
Moderate or severe liver disease	1.4%	0.8%	<.0001	1.5%	1.5%	.0375
Metastatic carcinoma	6.9%	3.1%	<.0001	6.8%	6.7%	.0193
AIDS/HIV	1.1%	0.4%	<.0001	1.2%	1.1%	<.0001

ED indicates emergency department; ONS, oral nutritional supplement.

[a]Matched episodes excluded tube feeding. Definitions of "admitted past 6 mo" and "readmitted within 30 d" were approximate as the underlying data represent dates as only month and year.

Table A2. Mean Episode Characteristics Across High and Low ONS Propensity Hospitals[a]

Episode Characteristics	Hospital Propensity to Use ONS					
	≤5th percentile	>95th percentile	*P*	≤50th percentile	>50th percentile	*P*
Age, y	48.9	49.8	<.0001	48.8	48.0	<.0001
Female	58.7%	57.6%	<.0001	58.8%	59.2%	<.0001
Race						
Black	12.1%	10.0%	<.0001	13.7%	12.5%	<.0001
Hispanic	7.7%	9.3%	<.0001	6.8%	7.3%	<.0001
White	57.4%	68.1%	<.0001	59.8%	63.0%	<.0001
Admitted past 6 mo	23.2%	24.9%	<.0001	23.2%	22.8%	<.0001
Admitted from ED	43.8%	44.7%	<.0001	43.0%	41.2%	<.0001
Readmitted within 30 d	14.1%	14.9%	<.0001	14.1%	13.8%	<.0001
Length of stay, d	4.9	4.7	<.0001	4.8	4.7	<.0001
Discharge to home	68.3%	68.9%	<.0001	68.3%	70.1%	<.0001
Charlson Comorbidity Index score	1.8	1.8	<.0001	1.8	1.8	<.0001
Charlson Index comorbidities						
Myocardial infarction	7.0%	7.1%	<.0001	7.0%	6.6%	<.0001
Congestive heart failure	12.0%	13.1%	<.0001	12.1%	11.9%	<.0001
Peripheral vascular disease	4.9%	6.2%	<.0001	5.0%	5.3%	<.0001
Cerebrovascular disease	5.7%	6.3%	<.0001	5.9%	6.0%	<.0001
Dementia	2.3%	2.1%	<.0001	2.2%	2.1%	<.0001
Chronic pulmonary disease	17.6%	20.1%	<.0001	17.8%	17.5%	<.0001
Connective tissue and rheumatic disease	2.0%	1.8%	<.0001	1.9%	1.9%	<.0001
Peptic ulcer disease	1.3%	1.4%	<.0001	1.3%	1.3%	<.0001
Mild liver disease	2.5%	2.5%	.7608	2.6%	2.4%	<.0001
Diabetes without complications	16.1%	16.3%	<.0001	16.2%	15.6%	<.0001

Diabetes with complications	2.9%	3.3%	<.0001	3.0%	3.0%	.1745
Paraplegia and hemiplegia	1.3%	1.3%	.0276	1.4%	1.3%	<.0062
Renal disease	7.7%	6.7%	<.0001	7.8%	6.9%	<.0001
Cancer	6.5%	6.1%	<.0001	6.4%	6.2%	<.0001
Moderate or severe liver disease	0.7%	0.7%	<.0001	0.7%	0.7%	<.0001
Metastatic carcinoma	2.9%	2.6%	<.0001	2.8%	2.6%	<.0001
AIDS/HIV	0.4%	0.5%	<.0001	0.4%	0.3	<.0001
No. hospitals	162	23		230	230	
No. episodes	12,885,871	2,044,231		21,587,029	24,506,535	

ED indicates emergency department; ONS, oral nutritional supplement.

[a]Hospitals were sorted by the fraction of their episodes that involved ONS use. Hospitals with ONS use at or below the 5th percentile (column 2) or the 50th percentile (column 5) were considered low ONS propensity hospitals, while ONS use at or above the 95th percentile (column 3) or the 50th percentile (column 6) were considered high ONS propensity hospitals. Mean episode characteristics were calculated and compared across the low ONS propensity and the high ONS propensity hospitals.

Table A3. Results of the Sensitivity Analysis: Length of Stay[a]

Propensity Score Threshold (as a Percentile of the 1:1 Matched Sample Difference)	**25th percentile**	**95th percentile**
Effect of ONS on LOS, d (SE)	−3.834[b] (0.984)	−0.886[b] (0.0352)
Predicted LOS without ONS, d	12.54	7.140
Predicted LOS with ONS, d	8.710	6.254
Change due to ONS use	−30.5%	−12.41%
Observations, n	792,280	7,604,616

LOS indicates length of stay; ONS, oral nutritional supplements.

[a]Instrumental variables regression results were from samples of ONS episodes matched to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Standard errors took into account repeated observations of the same individual.

[b]Significant at the 1% level.

Table A4. Results of the Sensitivity Analysis: Episode Cost[a]

Propensity Score Threshold (as a Percentile of the 1:1 Matched Sample Difference)	**25th percentile**	**95th percentile**
Effect of ONS on episode cost (SE)	−$12,858[b] ($19.79)	−$3259[b] ($2.09)
Predicted episode cost without ONS	$31,759	$14,114
Predicted episode cost with ONS	$18,901	$10,855
Change due to ONS use	−40.5%	−23.1%
Observations, n	792,280	7,604,616

ONS indicates oral nutritional supplement.

[a]Instrumental variables regression results were from samples of ONS episodes matched to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. Dependent variable in the regressions was log of episode cost. Costs are in 2010 dollars. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Predicted episode costs used Duan's smearing estimator. Standard errors took into account repeated observations of the same individual.

[b]Significant at the 1% level.

Table A5. Results of the Sensitivity Analysis: 30-Day Readmission[a]

Propensity Score Threshold (as a Percentile of the 1:1 Matched Sample Difference)	**25th percentile**	**95th percentile**
Effect of ONS on probability of readmission (SE)	0.0045 (0.00337)	−0.0090[b] (0.00209)
Predicted readmission probability without ONS	0.316	0.319
Predicted readmission probability with ONS	0.320	0.310
Change due to ONS use	1.3%	−2.8%
Observations, n	569,706	5,537,721

ONS indicates oral nutritional supplement.

[a]The 30-day readmission window was approximate as only the month and year were observed in the data. Instrumental variables regression results were from samples of ONS episodes matched to non-ONS episodes on propensity to receive ONS. Terminal episodes and tube-fed episodes were excluded. The instrument was the fraction of episodes in a given hospital in a given quarter involving ONS use. Standard errors took into account repeated observations of the same individual.

[b]Significant at the 1% level.

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