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ORIGINAL PAPER

Hospital readmission among elderly patients

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Abstract This study investigates the incidence and determinants of hospital readmissions among elderly patients in Norway. The analyses are based on registered data on inpatient admissions to public hospitals from 1999 to 2006. During this period, mean length of stay in hospital decreased, while readmission rates increased. Probit and instrumental variable regression models are applied for the analyses. The results indicate that longer length of stay in the hospital is associated with lower probability of readmission. A patient's age, comorbidities, and complexity of the treatment procedure are positively associated with readmissions, while higher number of diagnostic procedures negatively affects hospital readmission. Finally, patients discharged to institutions are more likely to be readmitted to the hospital.

Keywords Prospective payments · Readmission · Length of stay · Discharge destination

JEL Classification I11 · I18

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Introduction

In many countries, hospital financing is based on a prospective payment system, also called activity-based financing, where hospitals are paid a pre-determined rate based on the Diagnosis Related Group (DRG) prices for each admission depending on the patient's illness, regardless of the length of stay in hospital or intensity of care. This payment system may provide economic incentives for hospitals to control costs and/or incentives to increase treatment activity. The evidence on prospective payments suggests that the system has been successful in reducing costs [33, 42], but it has also resulted in early discharges [27, 35] which has created many concerns because of the rise in unplanned readmission rates [7, 25, 30, 36], morbidity, and mortality [6].

Several studies demonstrate increased rates of unplanned hospital readmission and reduction in length of stay [5, 7, 30]. In the United States, 30-day readmission rates among patients with heart failure increased from 17 to 20 % between 1993 and 2006, followed by about 26 % reduction in the mean length of stay, i.e., from 8.6 to 6.4 days [7].

Unplanned hospital readmissions are considered an outcome indicator reflecting quality of care [13, 45]. The rise in such readmissions has caused wide concerns in many countries not only concerning the quality of hospital services but also because of the burden placed on patients and treatment costs [1, 23]. For instance, inpatient emergency care is the most expensive type of health care services [1, 16, 21]. Apart from these issues, unplanned readmissions cause delays in elective admissions.

Elderly patients are at increased risk for readmission to the hospital [14, 39, 47]. These patients are frailer and often have to rely on support from their families or community care institutions. In Norway, 13 % of the population is aged

67 years or older, and it is expected that this proportion will increase to 19 % in 2030 (Statistics Norway 2003). With the growing number of elderly requiring hospital care, it is important to provide more information on the incidence and determinants of unplanned readmissions among these patients. Studies of this kind are scarce in Norway. Using data for 1996, Heggestad [20] studied the association between hospital risk factors and readmissions among elderly patients in Norway. She found that admissions to the hospitals with relatively shorter length of stay increased the risk for readmission. The study focused on observations for 1 year prior to the implementation of activity-based financing in 1997, and hence, is not necessarily relevant for the present financing system.

The objective of the present study is to add to the literature on the risk for unplanned readmissions and provide a better insight on the incidence and determinants of hospital readmissions among elderly patients in Norway under an activity-based financing system. The findings might be useful for the health authorities in implementation of appropriate strategies or interventions for reducing readmission rates.

The present study explores the relationship between the length of hospital stay and unplanned readmissions, also controlling for the setting to which the patients are discharged, patient characteristics, and DRG and hospital specific effects. The empirical analyses are based on unique register data on admissions to all public hospitals in Norway for a period of 8 years (1999–2006). The study identifies DRG categories with high incidence of readmission rates, providing a sample of around 1 million hospital admissions for patients 60 years of age or older at 63 public hospitals. Probit and instrumental variable regression models are applied for the analysis. The latter model is used to correct for the potential endogeneity of the length of stay as an explanatory variable.

Descriptive statistics indicate that over a period of 8 years, the mean length of stay in the hospital has decreased by 13 %, accompanied by a 14 % increase in readmission rates. The regression results indicate that longer length of stay is associated with lower probability of readmission. Patient's age, number of diagnoses, and complexity of the treatment procedure are also positively associated with readmission, while a higher number of diagnostic procedures performed negatively affects hospital readmission. Finally, patients discharged to institutions (nursing homes or other care institutions) are more likely to be readmitted compared with patients discharged to personal homes.

The paper is organized as follows. Section 2 provides an overview of the related literature on hospital readmission. Research questions are discussed in Sect. 3. In Sect. 4, data and descriptive statistics are presented. The empirical framework is presented in Sect. 5, followed by presentation of the results in Sect. 6, and conclusions in the final section.

Related literature

Hospitals' incentives to discharge patients earlier have been associated with increased morbidity and mortality after discharge [6], increased discharge rates to nursing homes [29, 38, 41] and unplanned readmissions [7, 25, 36]. Recent studies in the United States report that 20–26 % of elderly patients were rehospitalized within 30 days after discharge, while over 30 % were rehospitalized within 90 days [23, 24].

The risk for unplanned readmissions may depend on several factors. One important factor is the type of illness or diagnosis, where cancer, cardiac diseases, and obstructive lung diseases are the most common diagnoses associated with the risk for unplanned readmissions [3, 26]. Disease progression, surgical complications, and infections are found to be among the reasons for such readmissions. For instance, the readmission risk for cardiac surgery patients is related to the various complications that these patients may experience following surgery [11]. Other factors influencing hospital readmissions include a patient's demographic factors, clinical factors (e.g., comorbidities), social status, and type of health care provider [9, 23, 26, 34, 37, 43].

There is also some evidence that patients discharged to nursing homes or other care institutions were more likely to be readmitted to the hospital [28, 43]. However, the impact of discharge destination on readmissions is not quite clear and there is some indication that the results may vary depending on the diagnosis, comorbidities, and the level of care received at nursing homes. For instance, Camberg et al. [8] found that patients with chronic obstructive pulmonary disease and patients with dementia who were discharged to nursing homes were less likely to be readmitted within 30 days after discharge than patients discharged to personal homes, but they found no significant effect for stroke patients.

Research questions

The study has several objectives. First, it aims to identify which diagnoses (DRGs) have the highest frequency for readmission. Next, it examines the variation in the average length of hospital stay and readmission rates over time. The main objective of the study is then to identify the determinants of hospital readmissions among elderly patients. An important question in this context is whether length of stay in the hospital is associated with unplanned readmissions. Furthermore, do patient-specific factors and discharge destination of patients (nursing homes and other care institutions vs. personal homes) have an impact on readmissions?

Finally, is there a difference between the determinants of short-term and long-term readmissions, i.e., within 30 and 90 days of discharge, respectively?

Data and descriptive statistics

Data sources

The data sets used in this study are register data on inpatient admissions to all public hospitals for the period 1999–2006 provided by the Norwegian Patient Registry. These data are year-specific and include all hospital stays with individual records on each patient such as age, gender, type of admission, main and secondary diagnoses, date of admission, discharge date, etc. The data are cross-sectional since it is not possible to follow patients from 1 year to another.

Data specifications

The study sample was constructed as follows. Admissions for patients under 60 years of age were excluded. Planned readmissions such as dialysis, chemotherapy for treatment of cancer, etc., were also excluded. Such readmissions are part of a regular treatment plan which requires frequent hospital admissions, and hence, do not count as unplanned readmissions. Therefore, the variable *readmission* considers only unplanned readmissions within 30 or 90 days after the initial discharge from hospital. Since the data do not allow us to track patients from 1 year to another, all admissions during the month of December were excluded. In this way, one can trace all readmissions following the initial discharge during January to November. Similar reasoning applies for readmissions within 90 days, so that admissions during the last 3 months of the year were excluded. Finally, DRGs with the highest frequency of hospital readmissions were identified. All observations except for the top 30 DRGs with the highest readmission rates were then excluded, providing a sample of around 1 million patient observations for 30-day readmissions and around 800,000 observations for 90-day readmissions.

Descriptive statistics

Table 1 presents the most common DRG-categories for hospital readmission among elderly patients. The majority of these DRGs have been pointed out as the main DRGs related to readmissions in several studies [3, 23, 26, 34, 37]. As evident from the table, cancer diagnoses, lung diseases such as chronic obstructive pulmonary disease and pneumonia, cardiac diseases such as circulatory disorders, angina and heart failure are the most common DRGs for readmissions.

Figure 1 illustrates the average length of stay in the hospital across the 30 DRGs. Length of stay in the hospital has, on average, decreased by about 13 % over time, that is from 7.8 days in 1999 to 6.8 days in 2006. Figure 2 displays the incidence of unplanned hospital readmissions within 30 and 90 days after initial discharge. As evident, there is a gradual increase in readmission rates over time, from 15 % in 1999 to 17.4 % in 2006 for 30 days readmissions, and from 24 % in 1999 to 26 % in 2006 for 90-day readmissions. These rates are quite similar to the reported readmission rates in other European countries [9, 18, 46] but are lower than those reported in the United States [7, 23, 24].

Table 2 presents the variables used in the analysis and their definitions. The variables *Secondary diagnosis* and *Complex* are included as proxies for severity of illness. The dummy variable *Complex* reflects the coding of DRGs into complex or noncomplex procedures according to the Norwegian DRG system. Such coding shows the complexity of a procedure and resources used for treatment of patients. The variable *Procedures* indicates the number of diagnostic procedures performed per patient. In many cases, there are no other diagnostic procedures than the main examination, explaining why the average for this variable is less than unity.

Table 3 provides the summary statistics for the two samples, indicating that 17 % of patients are readmitted to the hospital within 30 days after the initial discharge, while 25 % are readmitted within 90 days. The statistics are otherwise quite similar for the two samples. The average length of stay is over 7 days. The distribution of male and female patients is equal with an average age of 77 years and two secondary diagnoses. Finally, 25 % of all patients are discharged from hospital to an institution.

The empirical framework

The dependant variable, *Readmission*, is a binary variable that takes the value 1 for readmitted patients. R^* is the latent readmission variable and cannot be observed, but we can observe whether or not a patient is readmitted to the hospital, i.e., $R = 1$ if $R^* > 0$ and $R = 0$ when there is no readmission. Hence, the probability that a patient is readmitted is given by the following probit model:

$$\Pr\left(R_{ijt} = 1\right) = \Phi\Big(\alpha + \beta_1 \mathrm{LOS}_{ijt} + \beta_2 A_{ijt} + \beta_3 A_{ijt}^2 + \beta_4 M_{ijt} + \beta_5 S_{ijt} + \beta_6 P_{ijt} + \beta_7 C_{ijt} + \tau_t + \delta_d + v_j + \varepsilon_{ijt}\Big)$$
$$i = 1, 2, \ldots, N\, j = 1, 2, \ldots, J\, t = 1, \ldots, T\, d = 1, \ldots, D \quad (1)$$

where i denotes patients, j hospitals, and t time. R is the probability of readmission within 30 or 90 days after

Table 1 30-day readmission rates by DRG type

DRG	Observations	Readmission rates	Definition
403	16,493	25.39	Lymphoma and non-acute leukemia, without complication (w/o cc)
346	15,902	25.03	Malignancy, male reproductive system, with complication (w cc)
203	14,692	24.35	Malignancy of hepatobiliary system or pancreas
88	48,142	24.09	Chronic obstructive pulmonary disease
404	14,002	23.16	Lymphoma and non-acute leukemia, w/o cc
172	26,608	23.13	Digestive malignancy, w cc
87	12,340	22.85	Pulmonary edema and respiratory failure
82	36,145	22.66	Respiratory neoplasms
122	40,436	21.82	Circulatory disorders with acute myocardial infarction (AMI), w/o cc
121	32,672	21.24	Circulatory disorders with AMI, w cc
395	19,044	20.05	Blood cell disorders
79	12,720	19.35	Respiratory infections and inflammations, w cc
140	62,784	19.24	Angina pectoris
173	13,286	18.87	Digestive malignancy, w/o cc
475	15,612	18.07	Respiratory system diagnosis with ventilator support
127	58,996	17.18	Heart failure and shock
182	33,418	16.39	Esophagitis, gastroint and miscellaneous digest disorders, w cc
89	78,337	16.34	Pneumonia and pleurisy, w cc
138	27,212	16.72	Cardiac arrhythmia and conduction disorders, w cc
316	22,183	16.70	Kidney failure
320	20,666	15.96	Kidney and urinary tract infections, w cc
416	20,972	14.61	Septicemia
467	17,218	12.12	Other factors influencing health status
139	36,410	11.75	Cardiac arrhythmia and conduction disorders, w/o cc
183	41,078	11.23	Esophagitis, gastroint and miscellaneous digest disorders, w/o cc
210	35,028	11.11	Hip and femur procedures except major joint, w cc
143	23,420	10.77	Chest pain
243	34,215	9.81	Medical back problems
14	74,528	8.89	Specific cerebrovascular disorders
209	72,289	5.87	Major joint and limb reattachment procedures

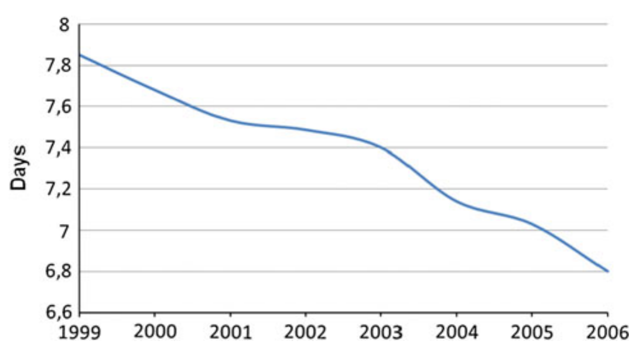

Fig. 1 Length of stay in the hospital

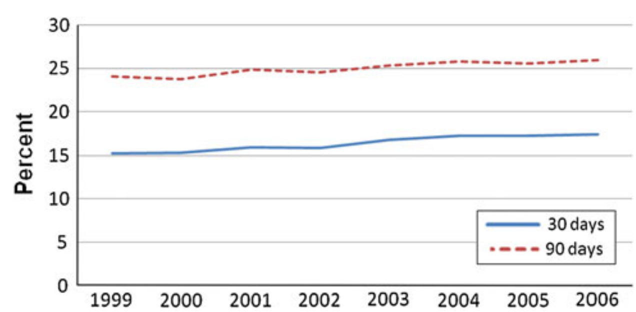

Fig. 2 Unplanned readmission rates

discharge. Φ is the normal cumulative density function. The notation for right hand side variables is as follows: patient's length of stay in hospital (LOS), age (*A*), male patient (*M*), number of secondary diagnoses (*S*), number of diagnostic procedures (*P*), complex DRG (*C*). Further, τ is a set of time dummies (month, year, and their interactions), δ is a set of DRG dummies to control for DRG specific effects, v is a set of dummy variables for hospitals in order to account for hospital-specific effects and ε is an error

Table 2 Variable definition

Variable	Definition
Readmission	Readmitted to hospital = 1, 0 otherwise
LOS	Length of hospital stay in days
Age	Patient's age in years
Male	Male patient = 1, 0 otherwise
Secondary diagnosis	Number of secondary diagnoses, varying from 0 to 10
Procedures	Number of diagnostic procedures, varying from 0 to 7
Complex[a]	Complex DRG = 1, 0 otherwise
Institution	Discharge to nursing home facility/care institution = 1, 0 otherwise
Time dummies	1999 to 2006: year dummies, month dummies and their interactions
DRG dummies	30 DRGs
Hospital dummies	63 hospitals

[a] All DRGs are classified as complex or non-complex diagnoses in the Norwegian DRG-system

Table 3 Summary statistics; 1999–2006

Variable	30-day readmission		90-day readmission	
	Mean	SD	Mean	SD
Readmission	0.17	0.37	0.25	0.43
LOS	7.34	8.29	7.31	8.28
Age	76.65	8.72	76.71	8.72
Male	0.48	0.50	0.49	0.50
Secondary diagnosis	2.18	1.75	2.16	1.74
Procedures	0.52	1.00	0.51	0.99
Complex	0.28	0.45	0.28	0.45
Institution	0.25	0.43	0.25	0.43
Observations	976,848		796,403	

term with mean zero and a standard normal distribution with variance one.

In order to capture the effect of a patient's discharge destination on the probability of readmission, the variable *Institution* is also included as control variable in a separate regression model. This variable equals unity when a patient is discharged to an institution (nursing home or other care facility).

Endogeneity problem

A potential problem in estimating Eq. (1) is the endogeneity of the variable LOS, which implies a correlation between the length of stay and the error term, ε. For example, more severely ill patients require more care and therefore they may stay longer in the hospital. If length of stay is endogeneous, then the estimated coefficient is biased. Without accounting for endogeneity, the effect of length of stay on readmission will be underestimated. An instrumental variable approach is a useful way to obtain consistent estimates of the parameters of the readmission equation. An instrument should be correlated with the length of stay and independent of the error term. Any instruments that satisfy these two conditions generate consistent estimates of parameters [17, 40]. As instrument, I use the 1 year lag for the average length of stay over a whole year per DRG and per hospital ($\mathrm{ALOS}(\mathrm{drg})_{j,\,t-1}$).

Using an instrumental variable approach implies that in the first stage, the endogenous variable is regressed on the instrumental variable and other exogenous variables as in Eq. (2).

$$\mathrm{LOS}_{ijt} = \alpha_0 + \alpha_1 \mathrm{ALOS}(\mathrm{drg})_{j,t-1} + \gamma X + u_{ijt} \quad (2)$$

where α and γ are the set of parameters to be estimated. X represents the explanatory variables as in Eq. (1). The error term, u, captures the unobservable, e.g., the technology improvements as such. In the second stage, the predicted values of length of stay are inserted into the readmission equation.

Expected effects

Since hospitals have incentives to discharge patients earlier, one might expect that patients are more likely to be readmitted due to shorter stays, for example because of undetected infections. On the other hand, shorter stays may be a result of better care or treatment technology, and therefore having no effect on readmission. Hence, the effect of length of stay on readmission is not quite clear.

It is expected that older patients [34] and those with secondary diagnoses [4] are more likely to be readmitted. Also, one might expect that patients diagnosed with complex DRGs have serious condition, and hence, have higher chances of being readmitted compared with other patients [45]. Finally, more diagnostic procedures may indicate higher quality of care and thereby reduced likelihood for readmission.

Empirical results

The statistical software program used in the analyses is Stata version 12. Tables 4 and 5 report the estimated marginal effects from the probit and instrumental variable probit (IVprobit) regression models for 30 and 90 days readmissions, respectively. For continuous variables, the marginal effects are computed at the means of the independent variables. The marginal effect of a dummy variable indicates the discrete change as the dummy variable changes from zero to one, holding all other variables at their means.

For 30-day readmissions, both probit and IVprobit models indicate significant effect of length of stay on readmission. The estimated effects are negative, implying that patients with longer length of stay are less likely to be readmitted to the hospital. This result is consistent with the findings of several studies [7, 25, 30, 36], but inconsistent with the findings of some other studies [23, 48]. The inconclusive results could be related to the type or number of DRGs considered, or the time of the study period.

As evident from Table 4, the probit model provides smaller coefficient of the length of stay than the IVprobit model, indicating the underestimation of this variable as a predictor of readmission. This result is similar to the study by Malkin et al. [32]. The regression results show a marginal effect of −0.0003 in the probit model and −0.0023 in the IVprobit model. The estimated coefficients are statistically significant. According to the IVprobit model, a 1-day increase in the average length of stay reduces the probability of readmission within 30 days by 0.23 %.

The other control variables have all significant effects on the probability of readmission. For instance, patient's age is positively associated with readmission. However, the effect is diminishing with age. Findings from several studies indicate that readmitted patients are older [9, 26, 34, 37]. Further, male patients are more likely to be readmitted than female patients. This result is also supported by several studies [1, 14, 15, 34]. As expected, patients with more diagnoses and complex DRGs are more likely to be readmitted. This is similar to other studies showing that number of secondary diagnoses [4] and complexity of a DRG are important risk factors for unplanned readmissions among elderly [31, 45]. In addition, undergoing more diagnostic procedures reduces the likelihood of hospital readmission. Finally, patients discharged to institutions have 4 % higher probability of readmission than patients discharged to personal homes. This finding is supported by [28], but it is inconsistent with the finding in the study by Camberg et al. [8]. The year-specific predicted probabilities of 30-day readmissions are graphically illustrated in Fig. 3.

The results for the probability of readmissions within 90 days are presented in Table 5. Commenting on the key variables of interest, a 1-day increase in the average length of stay reduces the readmission probability by 0.25 %, while discharging a patient to an institution increases the probability of readmission by about 3 %. The remaining results are quite similar to the previous results.

As noted earlier, male patients were more likely to be readmitted to the hospital than female patients. Table 6 presents separate regression results for these patients. For brevity, the results are only reported for the 30-day readmissions. As evident, there is no major difference between male and female patients regarding the size of the estimates for length of stay and secondary diagnoses. However, age, complex DRG, and being discharged to an institution have stronger effect for men than women. For instance, the probability of readmission after being discharged to an institution is 5.4 % for male patients and 2.9 % for female patients. Figure 4 illustrates the predicted probability of readmission for men and women.

To examine the variation in DRG types, separate regressions were conducted for the subcategories of the study sample focusing on the top ten DRGs with the highest readmission rates (see Table 2). The results for the DRG-specific regressions reveal some differences (Table 7). As in the main analysis, length of stay has a negative and significant impact on the probability of readmission for six DRGs (346, 404, 172, 87, 122, and 121). Also for these DRGs patients discharged to institutions are more likely to be readmitted, where the effect is significant, except for DRG 172. Only for DRG 203, the impact of the length of stay is significantly positive. Patients with this diagnosis are also less likely to be readmitted after discharge to an institution. The remaining results indicate that both length of stay and discharge destination have no significant effect for DRGs 403, 88, and 82.

Additional analyses were also conducted. For brevity, only the main findings are reported in the following. The linear probability model using instrumental variable ordinary least squares regression provided smaller estimates of the length of stay, i.e., 0.0014 for 30-day readmission. Another analysis was performed using an alternative instrument variable. This instrument was defined as the average length of stay per DRG per hospital for 1 year before and 1 year after the admission date. This approach provided similar results as the main analysis. Finally, regression results using age categories showed that patients in their 60 s and 70 s were more likely to be readmitted than those over 80 years.

Discussion and conclusion

Using register data on inpatient admissions to all public hospitals in Norway, this study identified the top 30 DRGs for readmission among elderly patients aged 60 years or older, providing a sample of around one million

Table 4 Readmission within 30 days; marginal effects

	Probit		IV-probit	
	(1)	(2)	(1)	(2)
LOS	−0.0003***	−0.0006***	−0.0023***	−0.0022***
	(0.0000)	(0.0000)	(0.0003)	(0.0003)
Age	0.0085***	0.0094***	0.0087***	0.0097***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Age2	−0.0001***	−0.0001***	−0.0001***	−0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Male	0.0124***	0.0127***	0.0117***	0.0122***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Sec_diag	0.0077***	0.0075***	0.0103***	0.0095***
	(0.0002)	(0.0002)	(0.0005)	(0.0005)
Procedures	−0.0108***	−0.0103***	−0.0080***	−0.0080***
	(0.0005)	(0.0005)	(0.0007)	(0.0006)
Complex	0.0099*	0.0094*	0.0126**	0.0114**
	(0.0052)	(0.0052)	(0.0052)	(0.0052)
Institution	–	0.0363***	–	0.0402***
	–	(0.0009)	–	(0.0012)
$N = 795{,}468$				

All regressions include time, DRG, and hospital dummies; standard errors are in *parentheses*

For dummy variables discrete change from 0 to 1

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. *Baselines* Female; non-complex DRG

Table 5 Readmission within 90 days; marginal effects

	Probit		IV-probit	
	(1)	(2)	(1)	(2)
LOS	−0.0002**	−0.0003***	−0.0026***	−0.0025***
	(0.0001)	(0.0001)	(0.0005)	(0.0005)
Age	0.0155***	0.0162***	0.0158***	0.0166***
	(0.0008)	(0.0008)	(0.0008)	(0.0008)
Age2	−0.0001***	−0.0001***	−0.0001***	−0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Male	0.0142***	0.0144***	0.0133***	0.0138***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Sec_diag	0.0138***	0.0137***	0.0169***	0.0163***
	(0.0003)	(0.0003)	(0.0007)	(0.0006)
Procedures	−0.0147***	−0.0144***	−0.0112***	−0.0114***
	(0.0006)	(0.0006)	(0.0009)	(0.0009)
Complex	0.0131*	0.0127*	0.0163**	0.0152**
	(0.0069)	(0.0069)	(0.0070)	(0.0070)
Institution	–	0.0246***	–	0.0295***
		(0.0012)		(0.0016)
$N = 975{,}702$				

All regressions include time, DRG and hospital dummies; standard errors are in *parentheses*

For dummy variables discrete change from 0 to 1; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Baselines Female, non-complex DRG, discharged home

observations. Cancer, lung diseases, and heart diseases were the most common diagnoses for readmissions. Over a period of 8 years, the mean length of stay in the hospital decreased by 13 %, while readmission rates increased by 14 %. Besides a reduction in hospitalization time, other factors may have contributed to the rise in readmission rates. In fact, during the same period, patients' average number of secondary diagnoses (comorbidities) increased from less than 2 to above 2.5 over time and the share of patients treated for a complex condition increased from 20 to 35 %.

The present paper considers a large number of DRG categories over an 8-year time period, using an instrumental variable approach to identify causality, which is

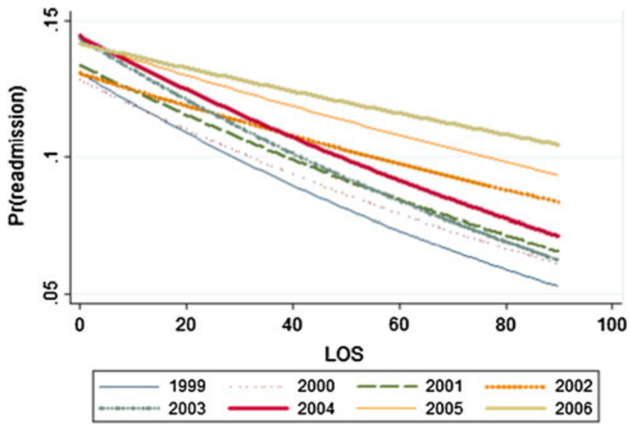

Fig. 3 *Predicted probabilities* 30-day readmission

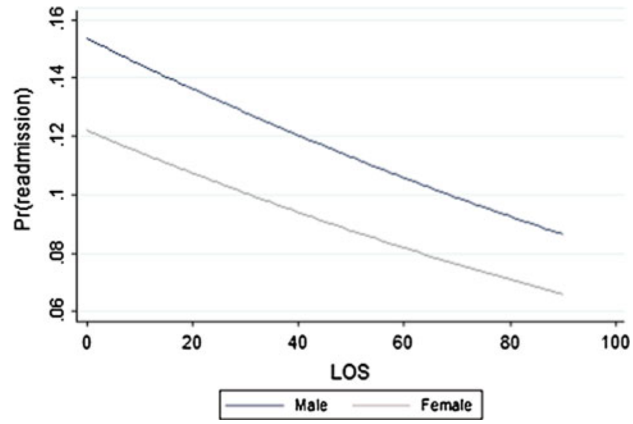

Fig. 4 *Predicted probabilities* 30-day readmission by gender

important due to the potential endogeneity of the length of stay. In fact, using non-IV and IV regression models, I show that the non-IV approach underestimates the impact of length of stay on the probability of readmission.

The findings indicate that patients with longer hospitalization time are less likely to be readmitted within 30 or 90 days after the initial discharge. For instance, an additional day in the hospital reduces the probability of readmission within 30 days by 0.0023. With an average readmission rate of 17 %, this amounts to a 1.4 % reduction in readmission rates. A direct comparison of the estimates of length of stay from this study with other studies is problematic due to the differences in methodology, variation with respect to age profile, number of specialties or DRGs, number of observations, time period, and variables included in the studies of readmission risks. However, it is possible to trace some similarities. For instance, it has been shown that a half-day increase in length of stay reduces readmission by 0.6 percentage points [32].

Also, patient characteristics have an impact on readmissions. For example, male patients are more likely to be readmitted. It has been argued that the higher readmission rates among male patients probably are due to higher severity of illness in men [15]. Patients treated for a complex condition and those with more secondary diagnoses also have higher probability of readmission. In contrast, patients undergoing more diagnostic procedures are less likely to be readmitted, which could reflect higher quality of care provided for these patients.

The role of discharge destination on readmissions is inconclusive in the literature. For instance, on the one hand, a study of elderly patients indicates that patients discharged to nursing homes are more likely to be readmitted [28]. On the other hand, there is some indication that

Table 6 Readmission within 90 days; IV-probit, marginal effects

	Male patients		Female patients	
	(1)	(2)	(1)	(2)
LOS	−0.0023***	−0.0021***	−0.0024***	−0.0023***
	(0.0005)	(0.0005)	(0.0004)	(0.0004)
Age	0.0133***	0.0145***	0.0053***	0.0059***
	(0.0010)	(0.0010)	(0.0008)	(0.0008)
Age2	−0.0001***	−0.0001***	−0.0001***	−0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sec_diag	0.0107***	0.0098***	0.0099***	0.0093***
	(0.0008)	(0.0007)	(0.0006)	(0.0006)
Procedures	−0.0097***	−0.0099***	−0.0060***	−0.0060***
	(0.0011)	(0.0010)	(0.0008)	(0.0008)
Complex	0.0177**	0.0150*	0.0087	0.0084
	(0.0082)	(0.0082)	(0.0066)	(0.0066)
Institution	–	0.0540***	–	0.0286***
	–	(0.0021)	–	(0.0015)
$N = 975{,}702$	473,186		502,441	

All regressions include time, DRG, and hospital dummies; standard errors are in *parentheses*

For dummy variables discrete change from 0 to 1; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Baselines Female, non-complex DRG, discharged home

Table 7 Readmission within 30 days; IV-probit estimates

	DRG403 (1)	DRG346 (2)	DRG203 (3)	DRG88 (4)	DRG404 (5)	DRG172 (6)	DRG87 (7)	DRG82 (8)	DRG122 (9)	DRG121 (10)
LOS	0.0041	−0.0545***	0.0402***	0.0073	−0.0875***	−0.0265**	−0.0234*	−0.0049	−0.0681***	−0.0460***
	(0.0254)	(0.0082)	(0.0081)	(0.0199)	(0.0221)	(0.0135)	(0.0122)	(0.0096)	(0.0071)	(0.0063)
Age	0.0235	0.1139***	0.0554**	0.0646***	0.1017***	0.0467**	0.1499***	0.0469**	0.0810***	0.0675***
	(0.0236)	(0.0246)	(0.0232)	(0.0144)	(0.0229)	(0.0182)	(0.0260)	(0.0183)	(0.01399)	(0.0160)
Age2	−0.0002	−0.0008***	−0.0004***	−0.0005***	−0.0007***	−0.0004***	−0.0011***	−0.0004***	−0.0005***	−0.0005***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Male	0.0586**	–	0.0662***	0.0899***	0.0222	0.0733***	−0.0071	0.0357**	−0.0232	−0.0240
	(0.0271)	–	(0.0231)	(0.0152)	(0.0269)	(0.0218)	(0.0257)	(0.0166)	(0.0157)	(0.0168)
Sec_diag	−0.0050	0.0811***	−0.0214**	0.0250	0.1608***	0.0515***	0.0168	0.0544***	0.0531***	0.0577***
	(0.0464)	(0.0105)	(0.0106)	(0.0181)	(0.0148)	(0.0161)	(0.0192)	(0.0129)	(0.0079)	(0.0097)
Procedures	−0.0847	−0.0627***	−0.1247***	−0.1659***	0.0383	−0.0155	−0.0451	−0.0221	−0.0905***	−0.0126
	(0.0687)	(0.0218)	(0.0224)	(0.0343)	(0.0463)	(0.0266)	(0.0378)	(0.0318)	(0.0115)	(0.0111)
Institution	0.0367	0.1628***	−0.2742***	0.0598	0.2487***	0.0687	0.3187***	−0.0414	0.5607***	0.3379***
	(0.1061)	(0.0405)	(0.0366)	(0.0637)	(0.0828)	(0.0597)	(0.0454)	(0.0402)	(0.0165)	(0.0174)
N	16,490	15,902	14,692	48,070	13,999	26,576	12,340	36,138	40,436	32,672

All regressions include time, DRG and hospital dummies; standard errors are in *parentheses*. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

DRG403 Lymphoma and non-acute leukemia, without complication, *DRG346* malignancy, male reproductive system, with complication (w cc), *DRG203* malignancy of hepatobiliary system or pancreas, *DRG88* chronic obstructive pulmonary disease, *DRG404* lymphoma and non-acute leukemia, w/o cc, *DRG172* digestive malignancy, w cc, *DRG87* pulmonary edema and respiratory failure, *DRG82* respiratory neoplasms, *DRG122* circulatory disorders with acute myocardial infarction (AMI), w/o cc, *DRG121* circulatory disorders with AMI, w cc the risk of readmission among these patients may vary depending on their diagnosis and comorbidities or the level of care received at nursing homes [8]. The present study cannot directly control for the quality of care after the discharge from hospital, but the results indicate that patients discharged to institutions are more likely to be readmitted than those discharged to personal homes. This is probably because of the higher frailty among these patients. Finally, the probability of readmission within 30 days of discharge is slightly higher than 90-day readmission (4 and 3 %, respectively). One possible explanation is that a 30-day phase after discharge represents a greater risk factor, while as the time after discharge passes, the likelihood of post-discharge complications decreases.

Hospitals as providers of health care services have an important role in providing adequate care for patients who are at risk for readmission. Policies targeting at better discharge planning such as patient follow-up programs by outpatient consultations, general practitioners, or home visits by nurses have shown to be effective in reducing readmissions [2, 12, 19, 44]. Also, better cooperation between hospitals, nursing homes, patients and their families seems to have a positive effect [10, 22, 37]. Other interventions suggested in the literature include a rewarding system for hospitals with readmissions below a certain level or reduction of reimbursements as a "penalty" for readmitted patients. In fact, the recent health care reform in the United States implies that hospitals with high readmission rates for certain conditions which should be potentially preventable with the delivery of proper health care, would be subject to a payment withhold on their DRG payments [49].

With the available data, the present study cannot provide estimates of cost savings due to the shorter length of stay or identify how many readmissions were in fact unpreventable. However, among the 30 DRGs examined, readmissions occurred at a rate of 17 % within 30 days and 25 % within 90 days of discharge. Accordingly, health care expenditures for readmitted patients increased from about €64 million in 1999 to €102 million in 2006, i.e., by 59 %.[1] Readmissions are costly. Hence, preventing unnecessary readmissions is obviously important. However, the finding that length of stay matters does not necessarily imply that patients should stay longer in hospital. If the costs of longer stays are high, the gains from a reduction in readmission rates may not justify the costs.

The growing number of elderly patients being readmitted to hospitals may indicate poor hospital performance. For many diagnoses, readmissions should not be necessary if patients receive proper care. Requiring that hospitals should meet some minimum quality standards, such as minimum-stay laws for certain DRGs with high readmission risk, might be a good policy for reducing readmissions. In this regard, the payment mechanism is obviously important. As long as the payment system does not account for increased length of stay, incentives to discharge patients earlier will remain. Hence, policies for reducing unnecessary readmissions might involve a redesign of the payment system. Introducing a rewarding system for good performance, e.g., low readmission rates, and a penalty system for poor performance, e.g., for higher-than-expected readmission rates, could be other options for reducing readmissions.

As shown in this study, a number of other factors influence readmission rates. For instance, patients with certain characteristics and those discharged to institutions face a higher risk for readmission. By acknowledging these facts and identifying high-risk patients, intervention policies such as better discharge transition programs and informing patients and their families about what they should be aware of after hospital discharge could be useful strategies for dealing with readmissions.

Starting in 2012, the most recent health care reform in Norway aims at better cooperation between hospitals and municipalities regarding patients who are ready to be discharged to a community care institution. In fact, municipalities face a penalty for each additional day beyond the scheduled discharge date set by the hospital. Such a penalty system may reduce hospital costs, facilitate patient transition and reduce waiting times for hospital treatment. However, since patients discharged to an institution are more likely to be readmitted, the question for future research is whether the intention to shorten hospitalization time would further increase readmission rates.

In conclusion, this study has aimed to provide a better understanding of the impact of hospital length of stay, discharge destination, and patient characteristics on unplanned readmissions and suggested policy tools for reducing readmission rates. This is important since unplanned readmissions are often considered a performance indicator for quality of hospital care.

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[1] All prices were converted to 2010 prices using consumer price index by Statistics Norway. Costs were calculated by multiplying the total number of DRG weights for readmitted patients by the payment rate per DRG (DRG weight reflects the average resources used for treatment of patients).

Conflict of interest None.

References

1. Anderson, G.F., Steinberg, E.P.: Hospital readmissions in the Medicare population. N. Engl. J. Med. **311**(21), 1349–1353 (1984)
2. Andersen, H.E., Schultz-Larsen, K., Kreiner, S., Forchhammer, B.H., Eriksen, K., Brown, A.: Can readmission after stroke be prevented? Results of a randomized clinical study: a postdischarge follow-up service for stroke survivors. Stroke **31**, 1038–1045 (2000)
3. Ashton, C.M., Kuykendall, D.H., Johnson, M.L., Wray, N.P., Wu, L.: The association between the quality of inpatient care and early readmission. Ann. Intern. Med. **122**(6), 415–421 (1995)
4. Au, S.Y., Chan, K.M., Chan, Y.H., Pang, W.S.: Early unplanned readmission of elderly in Singapore: a retrospective study. Ann. Acad. Med. Singap. **31**(6), 738–744 (2002)
5. Baker, D.W., Einstadter, D., Husak, S.S., Cebul, R.D.: Trends in postdischarge mortality and readmissions: has length of stay declined too far? Arch. Intern. Med. **164**(5), 538–544 (2004)
6. Boockvar, K.S., Halm, E.A., Likte, A., Silberzweig, S.B., McLaughlin, M.A., Penrod, J.D., Magaziner, J., Koval, K., Strauss, L., Siu, A.L.: Hospital readmissions after hospital discharge for hip fracture: surgical and nonsurgical causes and effect on outcomes. J. Am. Geriatr. Soc. **51**(3), 399–403 (2003)
7. Bueno, H., Ross, J.S., Wang, Y., Chen, J., Vidán, M.T., Normand, S.L.T., Curtis, J.P., Drye, E.E., Lichtman, J.H., Keenan, P.S., Kosiborod, M., Krumholz, H.M.: Trends in length of stay and short-term outcomes among Medicare patients hospitalized for heart failure 1993–2006. J. Am. Med. Assoc. **303**(21), 2141–2147 (2010)
8. Camberg, L.C., Smith, N.E., Beaudet, M., Daley, J., Cagan, M., Thibault, G.: Discharge destination and repeat hospitalizations. Med. Care **35**(8), 756–767 (1997)
9. Chambers, M., Clarke, A.: Measuring re-admission rates. Br. Med. J. **301**, 1134–1136 (1990)
10. Coleman, E.A., Parry, C., Chalmers, S., Min, S.-J.: The care transitions intervention: results of a randomized controlled trial. Arch. Intern. Med. **166**, 1822–1828 (2006)
11. Fasken, L.L., Wipke-Tevis, D.D., Sagehorn, K.K.: Factors associated with unplanned readmissions following cardiac surgery. Prog. Cardiovasc. Nurs. **16**(3), 107–115 (2001)
12. Hernandez, A.F., Greiner, M.A., Fonarow, G.C., Hammill, B.G., Heidenreich, P.A., Yancy, C.W., Peterson, E.D., Curtis, L.H.: Relationship between early physician follow-up and 30-day readmission among Medicare beneficiaries hospitalized for heart failure. J. Am. Med. Assoc. **303**(17), 1716–1722 (2010)
13. Goldacre, M.J., Henderson, J., Graveney, M.J.: Readmission rates. Br. Med. J. **302**, 414 (1991)
14. Gooding, J., Jette, A.M.: Hospital readmissions among the elderly. J. Am. Geriatr. Soc. **33**, 595–601 (1985)
15. Graham, H., Livesley, B.: Can re-admission rates to a geriatric medical unit be prevented? Lancet **321**, 404–406 (1983)
16. Grumbach, K., Keane, K.D., Bindman, A.: Primary care and public emergency department overcrowding. Am. J. Public Health **83**, 372–378 (1993)
17. Gujarati, D.N.: Basic econometrics, 4th edn. McGraw-Hill Higher Education, USA (2003)
18. Haines-Wood, J., Gilmore, D.H., Beringer, T.R.: Re-admission of elderly patients after in-patient rehabilitation. Ulst. Med. J. **65**, 142–144 (1996)
19. Hansen, F.R., Poulsen, H., Sørensen, K.H.: A model of regular geriatric follow-up by home visits to selected patients discharged from a geriatric ward: a randomized controlled trial. Aging (Milano) **7**(3), 202–206 (1995)
20. Heggestad, T.: Do hospital length of stay and staffing ratio affect elderly patients' risk of readmission? A nation-wide study of Norwegian hospitals. Health Serv. Res. **37**(3), 647–665 (2002)
21. Hennen, J., Krumholz, H.M., Radford, M.J., Meehan, T.P.: Readmission rates, 30 and 365 days postdischarge, among the 20 most frequent DRG groups, Medicare inpatients age 65 or older in Connecticut hospitals, fiscal years, 1991, 1992 and 1993. Conn. Med. **59**(5), 263–270 (1995)
22. Jack, B.W., Chetty, V.K., Anthony, D., Greenwald, J.L., Sanchez, G.S., Johnson, A.E., Forsythe, S.R., O'Donnell, J.K., Paasche-Orlow, M.K., Manasseh, C., Martin, S., Culpepper, L.: A reengineered hospital discharge program to decrease rehospitalization—a randomized trial. Ann. Intern. Med. **150**, 178–187 (2009)
23. Jencks, S.F., Williams, M.V., Coleman, E.A.: Rehospitalizations among patients in the Medicare fee-for-service program. N. Engl. J. Med. **360**(14), 1418–1428 (2009)
24. Jha, A.K., Orav, E.J., Epstein, A.M.: Public reporting of discharge planning and rates of readmissions. N. Engl. J. Med. **361**, 2637–2645 (2009)
25. Jones, J.: Re-admission rates: the price of early discharge. Health Serv. J. **96**, 825 (1986)
26. Johansen, H., Nair, C., Bond, J.: Who goes to the hospital? An investigation of high users of hospital days. Health Rep. **6**(2), 253–277 (1994)
27. Kahn, K.L., Keeler, E.B., Sherwood, M.J., Rogers, W.H., Draper, D., Bentow, S.S., Reinisch, E.J., Rubenstein, L.V., Kosecoff, J., Brook, R.H.: Comparing outcomes of care before and after implementation of the DRG-based prospective payment system. J. Am. Med. Assoc. **264**(15), 1984–1988 (1990)
28. Kerr, H.D., Byrd, J.C.: Nursing home patients transferred by ambulance to a VA emergency department. J. Am. Geriatr. Soc. **39**(2), 132–136 (1991)
29. Kosecoff, J., Kahn, K.L., Rogers, W.H., Reinisch, E.J., Sherwood, M.J., Rubenstein, L.V., Draper, D., Roth, C.P., Chew, C., Brook, R.H.: Prospective payment system and impairment at discharge—the "quicker and sicker" story revisited. J. Am. Med. Assoc. **264**(15), 1980–1983 (1990)
30. Kosiborod, M., Lichtman, J.H., Heidenreich, P.A., Normand, S.-L.T., Wang, Y., Brass, L.M., Krumholz, H.M.: National trends in outcomes among elderly patients with heart failure. Am. J. Med. **119**(7), 616.e1–616.e7 (2006)
31. Kossovsky, M.P., Pernger, T.V., Sarasin, F.P., Bolla, F., Borst, F., Gaspoz, J.M.: Comparison between planned and unplanned readmissions to a department of internal medicine. J. Clin. Epidemiol. **52**(2), 151–156 (1990)
32. Malkin, J.D., Broder, M.S., Keeler, E.: Do longer postpartum stays reduce newborn readmissions? Analysis using instrumental variables. Health Serv. Res. 35:5 Part II, 1071–1091 (2000)
33. McClellan, M.: Hospital reimbursement incentives: an empirical analysis. J. Econ. Manag. Strategy **6**(1), 91–128 (1997)
34. Moloney, E.D., Bennett, K., Silke, B.: Patient and disease profile of emergency medical readmissions to an Irish teaching hospital. Postgrad. Med. J. **80**, 470–474 (2004)
35. Newhouse, J.P., Byrne, D.J.: Did Medicare's prospective payment cause length of stay to fall? J. Health Econ. **7**(4), 413–416 (1988)
36. Pérès, K., Rainfray, M., Perrié, N., Emeriau, J.P., Chêne, G., Barberger-Gateau, P.: Incidence, risk factors and adequation of early re-admission among the elderly. Revue d'épidémiologie et de Santé Publique **50**, 109–119 (2002)
37. Phillips, R.S., Safran, C., Cleary, P.D., Delbanco, T.L.: Predicting emergency readmissions for patients discharged from the medical

service of a teaching hospital. J. Gen. Intern. Med. **2**(6), 400–405 (1987)
38. Qian, X., Russell, L.B., Valiyeva, E., Miller, J.: New evidence on Medicare's prospective payment system: a survival analysis based on the NHANES I epidemiologic follow-up study. Working papers, Rutgers University, Department of Economics, 2005; 06
39. Rich, M.W., Freedland, K.E.: Effect of DRGs on three-month readmission rate of geriatric patients with congestive heart failure. Am. J. Public Health **78**, 680–682 (1988)
40. Rivers, D., Vuong, Q.: Limited information estimators and exogeneity tests for simultaneous probit models. J. Econ. **39**(3), 347–366 (1988)
41. Rogers, W.H., Draper, D., Kahn, K.L., Keeler, E.B., Rubenstein, L.V., Kosecoff, J., Brook, R.H.: Quality of care before and after implementation of DRG-based prospective payment system—a summary of effects. J. Am. Med. Assoc. **26**(15), 1989–1994 (1990)
42. Russell, L.B., Manning, C.L.: The effect of prospective payment on Medicare expenditures. N. Engl. J. Med. **320**(7), 439–444 (1989)
43. Silverstein, M.D., Qin, H., Mercer, Q., Fong, J., Haydar, Z.: Risk factors for 30-day readmission inpatients $\geq$65 years of age. Baylor Univ. Med. Cent. Proc. **21**(49), 363–372 (2008)
44. Stewart, S., Vandenbroek, A.J., Pearson, S., Horowitz, J.D.: Prolonged beneficial effects of a home-based intervention on unplanned readmissions and mortality among patients with congestive heart failure. Arch. Intern. Med. **159**, 257–261 (1999)
45. Thomas, J.W., Holloway, J.J.: Investigating early readmissions an indicator for quality of care studies. Med. Care **29**(4), 377–394 (1991)
46. Victor, C., Jeffries, S.: The readmission of elderly people to hospital in an inner-city health district. Arch. Gerontol. Geriatr. **10**(1), 89–95 (1990)
47. Vinson, J.M., Rich, M.W., Sperry, J.C., Shah, A.S., McNamara, T.: Early readmission of elderly patients with congestive heart failure. J. Am. Geriatr. Soc. **38**, 1290–1295 (1990)
48. Westert, G.P., Lagoe, R.J., Keskimäki, I., Leyland, A., Murphy, M.: An international study of hospital readmissions and related utilisation in Europe and the USA. Health Policy **61**(3), 269–278 (2002)
49. Whelan, E.-M., Feder, J.: Payment reform to improve health care: ways to move forward. Cent. Am. Prog. 1–32 (2009)