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Local Health Units in Portugal: The Influence of Chronic Conditions on Inpatient Readmissions

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Keywords
Integrated health care · Vertical integration · Chronic conditions · Readmissions · Difference in differences · Statistical methods

Abstract
Background: In Portugal, a public policy established the Local Health Units (LHUs), merging primary and hospital care providers. LHUs are expected to provide better continuity and coordination of care, thus decreasing the number of unplanned readmissions among those with chronic conditions. This study aims to evaluate the influence of chronic conditions on the risk of readmission at LHUs. ***Methods:*** We used inpatient care administrative databases for the years 2002–2014 (n = 1,679,634). We assessed the effects of chronic conditions on the risk of readmission with a difference-in-differences technique, comparing LHUs with a control group. Multivariate Cox regression was used to evaluate time to readmission. ***Results:*** The risk of readmission decreased in four LHUs, but significantly only in two. Individuals with more chronic conditions presented a lesser risk of readmission at LHUs, in contrast to those in the control group. ***Conclusions:*** After adjusting for the number of chronic conditions and comorbidities, we concluded that LHUs may successfully decrease unplanned readmissions. Several challenges still have to be addressed to achieve a larger and long-lasting effect. Further investigation is needed to account for contextual and organizational effects that may explain differences across LHUs.

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Unidades Locais de Saúde em Portugal: a influência das condições crónicas nas readmissões

Palavras Chave
Cuidados de saúde integrados · Integração vertical · Condições crónicas · Readmissões · Diferença das diferenças · Métodos estatísticos

Resumo
Introdução: Em Portugal, uma política pública estabeleceu as Unidades Locais de Saúde (ULS) que resultam da integração de prestadores de cuidados de saúde primários e hospitalares. É expectável que as ULS prestem melhor continuidade e coordenação de cuidados de saúde e que, consequentemente, consigam reduzir o número de readmissões não planeadas em indivíduos com condições crónicas. O objectivo deste estudo foi avaliar a influência da existência de condições crónicas no risco de readmissão nas ULS. ***Métodos:*** Usámos a base de dados de morbilidade hospitalar referente aos anos 2002–2014 (n = 1.679.634). Avaliámos o efeito da existência de condições crónicas no risco de readmissão com a técnica diferença das diferenças, comparando as ULS com um grupo de controlo. Aplicámos uma regressão Cox para avaliar o tempo até ocorrência de readmissão. ***Resultados:*** O risco de readmissão diminuiu em 4 ULS; o efeito foi estatisticamente significativo em duas ULS. Indivíduos com maior número de condições crónicas apresentaram menor risco de readmissão nas ULS, em contraste com os indivíduos no grupo de controlo. ***Conclusões:*** Tendo em consideração o número de condições crónicas e de comorbidades num indivíduo, as ULS têm potencial para reduzir o número de readmissões não planeadas. Vários desafios devem ser endereçados de modo a serem alcançados resultados mais robustos e de efeito duradouro. Investigações futuras devem considerar possíveis efeitos contextuais e organizacionais que possam explicar a variabilidade de resultados entre ULS.

Introduction

More than half of the Portuguese adult population have at least one chronic condition, and one-third live with multiple chronic conditions [1]. Individuals with chronic conditions are expected to be high users of varying medical services [2]. Thus, these individuals face greater exposure to lack of continuity and coordination of care across the health system [2, 3]. Partly to address these concerns, some health systems have sought to merge health care providers of different levels of care into a single organization (vertical integration).

Following vertical integration, one expects a decrease in the risk of readmission for individuals with chronic conditions because of better continuity and coordination of care [4–6]. Reducing readmissions among individuals with chronic conditions is a policy objective for improving health care quality and efficiency. Addressing this problem is a concern to health systems because of the many impacts of aging populations, the increasing prevalence of multiple chronic conditions and the burden of disease. Moreover, readmissions are costly and disruptive of one's life. However, the evidence on the effects of vertical integration on quality of care indicators is mixed [7]. In Portugal, little evidence has been produced in regard to policies that have sought for better continuity and coordination of care across the health system such as that of the establishment of vertically integrated health care providers.

Since 1999, in the Portuguese National Health Service (NHS), vertical integration is set forth by the Local Health Units (LHUs) [8]. Selected public providers were reorganized by the Ministry of Health without a public rationale. LHUs were established between 1999 and 2012; currently, there are eight LHUs in the NHS, which coexist with other public providers. LHUs are accountable for the delivery of care for 12% of the Portuguese mainland population and for 16.9% of the NHS' budget for hospitals [9]. Notwithstanding, little is known about the performance of LHUs on quality of care indicators such as that of the 30-day readmission.

A previous study measured the effect of LHUs on readmissions [10]. The findings suggested that following vertical integration, the risk of readmission decreased in LHUs. However, the number of chronic conditions at the individual level was not accounted for. Given that chronic conditions and other comorbidities are the reason for many unplanned readmissions [2, 11–13], our aim was to evaluate the influence of chronic conditions on the risk of readmission in LHUs.

The objective of this study was twofold: (1) to assess the risk of readmission before and after vertical integration, after adjusting for the number of chronic conditions and the Elixhauser comorbidity index and (2) to ascertain associations of individuals' characteristics (sex, age group, number of chronic conditions and Elixhauser comorbidity index) with time to readmission.

Methods

Study Design

We evaluated the risk of readmission in LHUs before and after vertical integration with a difference-in-differences (DiD) technique. We considered an 8-year time frame for each LHU and compared with that of a control group (5 years before the integration [I–5], the year when the vertical integration occurred [I] and 2 additional years after integration [I+2]). The statistical model included the individuals' characteristics (individual risk of readmission, number of chronic conditions and Elixhauser comorbidity index) and a set of hospital dummies.

Cox regression was used to understand the association of an individual's characteristics (sex, age group, number of chronic conditions and Elixhauser comorbidity index) with time to readmission.

Data Sources and Eligibility Criteria

The Portuguese Central Administration for the Health System (ACSS) provided the administrative databases on inpatient care for the years 2002–2014. Databases included patient-level information registered at public mainland hospitals: unique encoded admission identifier, year, hospital identifier, sex, age, type of admission, discharge date, length of stay, discharge status, principal diagnosis, secondary diagnoses and procedures. The last three were coded with the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM). We considered the first 20 diagnoses of each admission (1 principal diagnosis and 19 secondary diagnoses).

We identified 9,523,432 eligible index admissions, after excluding admissions for the following reasons: data quality (9,111; 0.07%); specialized or low-volume hospital (132,515; 1.1%); deceased, transferred or left against medical advice (1,169,580; 9.4%); without at least 30-day post-discharge follow-up (911,485; 7.4%); and admitted for psychiatric diagnosis, rehabilitation or medical treatment of cancer (645,281; 5.2%). Among eligible index admissions, we selected for analysis those treated at LHUs (n = 845,275) or at hospitals that composed the control group (n = 834,359). No missing data were registered on the variables included in the study.

Intervention and Control Group Composition

The establishment of LHUs occurred in different years: the first in 1999 [8], one in February 2007 [14], three in September 2008 [15], one in November 2009 [16], one in June 2011 [17] and the last in October 2012 [18]. These hospitals that transitioned to a vertically integrated model are hereinafter considered as the intervention group (LHU). In contrast to a previous study [10], we increased the sample size by including data of an additional LHU. We excluded from the intervention group the LHU established in 1999 because data were not available for the period before the integration. Hence, we analyzed 7 out of 8 LHUs.

The control group included 6 public hospitals that were not vertically integrated. To compose the control group, we considered ACSS hospital benchmarking groups for financing purposes, created by hierarchical clustering as described elsewhere [19]. Control hospitals were similar in dimension and clinical complexity to those of the intervention group. We accounted for possible external systemic effects that could have influenced the evolution of readmissions. Thus, specialty and teaching hospitals, as well as public-private partnerships, were not included as controls.

Variables

The dependent variable was the occurrence of readmission within a 30-day time frame following an index admission. We identified unplanned readmissions using the Centers for Medicare & Medicaid Services (CMS) hospital-wide all-cause unplanned readmission measure (1: readmitted) [20].

Two complementary measures to assess the level of comorbidity and chronicity were used: Quan's updated version of the Elixhauser comorbidity index (1: comorbidity present) [21] and the Agency for Healthcare Research and Quality chronic condition indicator (1: chronic condition present) [22]. We used ICD-9-CM five-digit codes to compute both measures.

The individual risk of readmission was estimated with generalized linear mixed models at the specialty cohort level as described elsewhere (1: readmitted) [20]. To increase the robustness of this estimation we fitted the model considering all eligible index admissions (n = 9,523,432).

Statistical Methods

We used absolute and relative frequency to describe admissions to hospitals in the intervention and the control group by sex, age group (0–19, 20–44, 45–64, 65–84, ≥85), number of chronic conditions and Elixhauser comorbidity index (0, 1, 2, 3, 4, ≥5).

A DiD technique via unconditional logit model with fixed effects was used to analyze the effects of vertical integration on the risk of readmission. Given the large sample used, the bias in the unconditional estimator was small [23] and acceptable for the purpose of this research. To relax the parallel trend assumption for the DiD technique, we considered a differential trend model as described elsewhere [24].

The model was as follows:

$$\begin{aligned}\operatorname{logit}\left[Prob\left(Y_{ijt}=1\right)\right] &= \lambda_0 + \delta LHU_{ijt} + \gamma Post_{ijt} + \varphi_{jt} + Chron_{ijt} + Elix_{ijt} + RR_{ijt} \\ &+ \sum_{k}^{T} \alpha_{jk} Year_k + \sum_{k}^{T} \theta_{jk} Year_k LHU_{ijt} + \varepsilon_{ijt}\end{aligned}$$

where Y_{ijt} is a binary variable for episode i in hospital j in year t, assuming value 1 if it is readmission, and 0 otherwise; LHU_{ijt} is a binary variable taking on value 1 if hospital j in year t is an LHU, and 0 otherwise; $Post_{ijt}$ is a binary variable taking on value 1 for episode i in hospital j in year t post-integration, and 0 otherwise; φ_{jt} is a vector of hospital dummies; $Chron_{ijt}$ is a vector with the number of chronic conditions for individual i admitted to hospital j in year t; $Elix_{ijt}$ is a vector with the Elixhauser comorbidity index for individual i admitted to hospital j in year t; RR_{ijt} is a vector with the individual risk of readmission for individual i at hospital j in year t, computed via mixed effects logistic model, as detailed elsewhere [10]; $Year_k$ is a set of year dummies; and $Year_k LHU_{ijt}$ is the interaction between the terms Year and LHU.

Parallel trend assumption was tested using the nonlinear restriction

$$\frac{\sum \theta_{jk}}{\sum \alpha_{jk}} = 0\,.$$

We used Cox regression to study the association of an individual's characteristics with time to readmission. Hazard function measured the risk of readmission of an individual within a 30-day time frame, adjusting for sex, age group, number of chronic conditions

Table 1. Sample characteristics for LHUs and the control group by sex, age group, number of chronic conditions and Elixhauser comorbidity index (2002–2014)

	Total (n = 1,679,634)		LHUs (n = 845,275)		Controls (n = 834,359)	
	n	%	n	%	n	%
Sex						
Women	947,826	56.4%	471,566	55.8%	476,260	57.1%
Men	731,808	43.6%	373,709	44.2%	358,099	42.9%
Age group						
0–19 years	362,884	21.6%	171,594	20.3%	191,290	22.9%
20–44 years	308,598	18.4%	148,511	17.6%	160,087	19.2%
45–64 years	319,657	19.0%	159,725	18.9%	159,932	19.2%
65–84 years	555,524	33.1%	295,788	35.0%	259,736	31.1%
≥85 years	132,971	7.9%	69,657	8.2%	63,314	7.6%
Number of chronic conditions						
0	997,634	59.4%	498,858	59.0%	498,776	59.8%
1	282,529	16.8%	143,726	17.0%	138,803	16.6%
2	196,736	11.7%	99,850	11.8%	96,886	11.6%
3	120,637	7.2%	60,780	7.2%	59,857	7.2%
4	52,686	3.1%	26,437	3.1%	26,249	3.1%
≥5	29,412	1.8%	15,624	1.8%	13,788	1.7%
Elixhauser comorbidity index						
0	1,069,822	63.7%	534,957	63.3%	534,865	64.1%
1	293,571	17.5%	151,269	17.9%	142,302	17.1%
2	184,814	11.0%	92,403	10.9%	92,411	11.1%
3	84,654	5.0%	42,128	5.0%	42,526	5.1%
4	31,299	1.9%	16,045	1.9%	15,254	1.8%
≥5	15,474	0.9%	8,473	1.0%	7,001	0.8%

LHUs, Local Health Units.

and Elixhauser comorbidity index. We used univariate Cox regression to assess the covariates' association with time to readmission. Covariates with $p < 0.1$ were included in the multivariate model. The multivariate model was set up with a stepwise backward likelihood ratio data selection approach. A cutoff of $p < 0.05$ was considered to remove covariates from the final model. We proceeded with a visual inspection of Kaplan-Meier plots to assess the proportional hazards assumption. The analysis was conducted separately for the intervention and control group.

To compute the individual risk of readmission we used SAS University Edition. All other analyses were performed with Stata (v. 13). The confidence level was set at 95%.

Results

Our study included 1,679,634 index admissions (Table 1). LHUs accounted for 50.3% of index admissions. The frequency of admissions was greater among women, both in the LHUs and the control group (55.8 and 57.1%, respectively). Individuals admitted to LHUs were older, compared with those in the control group: the average age in LHUs was 51.3 ± 28.4 years and that for the control group 48.5 ± 28.9 years. The distribution of individuals by the number of chronic conditions and comorbidities was similar in both groups.

The control group exhibited higher readmission rates (Table 2). The readmission rate for men was of 5.6%, compared with that of 4.7% for women. Readmission rates increased with age (e.g. the readmission rate for the age group ≥85 years in LHUs was of 8.8%, in contrast to that of 11.5% for the control group). Readmission rates also increased with increasing number of chronic conditions (e.g. the readmission rate for individuals with five or more chronic conditions was 10.1% in LHUs and 12% in the control group). A similar pattern was observed for increasing number of comorbidities.

The parallel trend assumption was not observed for LHU2 and LHU4 (Table 3). Hence, the DiD results for

Table 2. Readmission rates for LHUs and the control group by sex, age group, number of chronic conditions and Elixhauser comorbidity index (2002–2014)

	Total (n = 85,385), 5.1% of total		LHUs (n = 40,779), 4.8% of total		Controls (n = 44,606), 5.3% of total	
	n	% of total	n	% of total	n	% of total
Sex						
Women	44,302	4.7%	21,290	4.5%	23,012	4.8%
Men	41,083	5.6%	19,489	5.2%	21,594	6.0%
Age group						
0–19 years	12,768	3.5%	5,583	3.3%	7,185	3.8%
20–44 years	8,904	2.9%	4,627	3.1%	4,277	2.7%
45–64 years	11,763	3.7%	5,697	3.6%	6,066	3.8%
65–84 years	38,521	6.9%	18,720	6.3%	19,801	7.6%
≥85 years	13,429	10.1%	6,152	8.8%	7,277	11.5%
Number of chronic conditions						
0	32,773	3.3%	16,299	3.3%	16,474	3.3%
1	17,367	6.1%	8,322	5.8%	9,045	6.5%
2	15,664	8.0%	7,230	7.2%	8,434	8.7%
3	11,172	9.3%	5,007	8.2%	6,165	10.3%
4	5,187	9.8%	2,349	8.9%	2,838	10.8%
≥5	3,222	11.0%	1,572	10.1%	1,650	12.0%
Elixhauser comorbidity index						
0	36,248	3.4%	17,906	3.3%	18,342	3.4%
1	18,798	6.4%	8,973	5.9%	9,825	6.9%
2	15,738	8.5%	7,182	7.8%	8,556	9.3%
3	8,808	10.4%	3,892	9.2%	4,916	11.6%
4	3,770	12.0%	1,791	11.2%	1,979	13.0%
≥5	2,023	13.1%	1,035	12.2%	988	14.1%

LHUs, Local Health Units.

those LHUs were interpreted with caution because the observed effects cannot be solely attributed to vertical integration. LHU1 and control hospitals had a total of 600,086 index admissions, where 11.6% (69,725) were from LHU1. The results suggested a greater risk of readmission for LHU1 compared with that of the control group (odds ratio [OR] 1.017, 95% confidence interval [CI] 0.940–1.101). We observed similar results for LHU4 (OR 1.240, 95% CI 1.149–1.338) and LHU6 (OR 1.076, 95% CI 0.992–1.166). The former showed a statistically significant result, albeit the parallel trend assumption was not verified (Wald test 10.74, p = 0.001). The risk of readmission for LHU2 compared with that of the control group decreased after vertical integration (OR 0.991, 95% CI 0.952–1.032). The results suggested a similar effect for LHU3 (OR 0.911, 95% CI 0.837–0.991), LHU5 (OR 0.860, 95% CI 0.790–0.936) and LHU7 (OR 0.937, 95% CI 0.866–1.013). The results were statistically significant for LHU3 and LHU5.

Both in the intervention and control group, the unadjusted hazard ratio (HR) suggested a decrease in the likelihood of readmission for women (Table 4). In older age groups, increasing number of chronic conditions and comorbidities were associated with a greater likelihood of readmission. Overall, LHUs presented a lesser risk of readmission for individuals with more chronic conditions and comorbidities, compared with that of the control group.

The results of multivariate Cox regression models stressed a similar risk pattern for sex and age in both groups. Women showed a lesser likelihood of readmission in the control group (LHU: HR 0.906, 95% CI 0.889–0.924; control group: HR 0.861, 95% CI 0.845–0.878). The risk of readmission increased across age categories, consistent with the unadjusted HRs (e.g. in LHUs, individuals aged ≥85 years had a 1.7 times greater likelihood of readmission than those aged 0–19 years). The adjusted HR in LHUs decreased with increasing number of chron-

Table 3. Risk of readmission for each LHU compared with that of the control group

	Sample size (LHU cases, %)	OR (95% CI)	R^2	Wald test	*p* value
LHU1	600,086 (69,725, 11.6%)	1.017 (0.940–1.101)	0.079	2.15	0.142*
LHU2	594,776 (62,738, 10.5%)	0.991 (0.952–1.032)	0.075	5.03	0.025
LHU3	603,417 (94,839, 15.7%)	0.911 (0.837–0.991)	0.083	1.06	0.304*
LHU4	589,376 (64,711, 11.0%)	1.240 (1.149–1.338)	0.079	10.74	0.001
LHU5	614,334 (83,973, 13.7%)	0.860 (0.790–0.936)	0.080	3.73	0.05*
LHU6	667,178 (136,817, 20.5%)	1.076 (0.992–1.166)	0.080	0.94	0.331*
LHU7	527,353 (28,246, 5.4%)	0.937 (0.866–1.013)	0.088	0.05	0.820*

Data were from an 8-year timeframe: 5 years before vertical integration, the year when vertical integration occurred and the following two years. Estimates are derived from DiD logistic regression and measure the independent effect of vertical integration on the risk of readmission (measured in OR). Statistically significant ORs <1 stress that the risk of readmission decreased at the LHU following vertical integration when compared with the control group. We tested the nonlinear restriction $\Sigma\theta_{jk}/\Sigma\alpha_{jk} = 0$ to assess parallel trend assumption for DiD. CI, confidence interval; DiD, difference in differences; LHU, Local Health Unit; OR, odds ratio. * Cases for nonrejection of the null hypothesis of Wald's statistical test, which provides evidence in favor of the parallel trend assumption.

ic conditions, contrasting to the pattern suggested by the unadjusted model. A different pattern was found in the control group, where individuals with three chronic conditions showed a greater likelihood of readmission (HR 1.472, 95% CI 1.398–1.549). Also, an increase in comorbidities was associated with a greater risk of readmission: individuals with five or more comorbidities at LHUs faced a likelihood of readmission 2.5 times greater than those who had no comorbidities.

Discussion

In this study, we assessed the risk of readmission before and after vertical integration, adjusted for an individual's number of chronic conditions and comorbidities. The association of an individual's characteristics with time to readmission was analyzed.

Following vertical integration, the risk of readmission did not evolve similarly across LHUs. We found evidence of a positive effect on decreasing the risk of readmission in four LHUs, but with statistical significance for two cases only. Our mixed results on the effect of vertical integration on readmissions are aligned with those suggested by other studies [4, 5, 7, 12, 25, 26]. Differences between LHUs may be a result of contextual factors, including that of the implementation process of vertically integrated health care providers in Portugal. The sole responsibility to operationalize the merging of providers was their own, thus yielding different models of care delivery with implications at an operational level. A study developed at LHUs to evaluate the perception of integration among professionals highlighted low levels of perception of clinical integration among physicians and nurses, which increased over time [27]. Hence, the ability to provide an interprofessional service delivery that can effectively address the expectations and care needs of those with chronic conditions evolved differently in each LHU. Moreover, LHUs did not receive formal guidance, monitoring or financial incentives by the Ministry of Health to decrease readmissions or to focus on specific needs of those individuals with chronic conditions.

In LHUs, the risk of readmission decreased with increasing number of chronic conditions, which may suggest that LHUs are more responsive to the needs of individuals with multiple chronic conditions. Given that LHUs are responsible for the entire care trajectory, individuals with multiple chronic conditions may be monitored closely, thus delaying or preventing readmissions [28]. Also, the interventions that each LHU defined for the period before, during, and after hospital discharge may partly explain this result. These interventions alone have little effect on 30-day readmission rates [29–31], but the effect increases with high-intensity multi-interventions, particularly among individuals with greater risk of readmission [32].

Variability on the risk of readmission signals room for improvement [33]. Key barriers to an effective continuum of care are partly configured by: (1) different models of governance and service delivery across vertically integrated providers [34]; (2) contextual factors (e.g. geographical distribution of providers and disparities in primary care resources [35]); (3) availability of digital health technologies (e.g. real-time data sharing across providers); and (4) the effect of time in fine-tuning a new organizational culture that vertical integration calls on across providers [34].

Table 4. Association of an individual's characteristics with time to readmission

Covariate	Coding	LHUs				Controls			
		unadjusted HR	95% CI	adjusted HR	95% CI	unadjusted HR	95% CI	adjusted HR	95% CI
Sex	0: men	reference		reference		reference		reference	
	1: women	0.863	0.846–0.880	0.906	0.889–0.924	0.797	0.782–0.811	0.861	0.845–0.878
Age group, years	0: 0–19	reference		reference		reference		reference	
	1: 20–44	0.957	0.920–0.995	0.928	0.893–0.966	0.706	0.680–0.733	0.683	0.658–0.710
	2: 45–64	1.096	1.056–1.137	0.839	0.807–0.872	1.007	0.973–1.042	0.713	0.688–0.740
	3: 65–84	1.970	1.912–2.030	1.281	1.238–1.325	2.059	2.004–2.116	1.197	1.158–1.236
	4: ≥85	2.784	2.685–2.887	1.716	1.647–1.787	3.167	3.065–3.272	1.755	1.689–1.823
Number of chronic conditions	0	reference		reference		reference		reference	
	1	1.792	1.745–1.840	1.298	1.251–1.347	2.001	1.950–2.053	1.398	1.347–1.452
	2	2.255	2.193–2.318	1.287	1.230–1.347	2.699	2.629–2.771	1.456	1.391–1.524
	3	2.578	2.498–2.661	1.266	1.203–1.333	3.215	3.122–3.310	1.472	1.398–1.549
	4	2.787	2.669–2.910	1.233	1.160–1.312	3.385	3.252–3.522	1.396	1.314–1.483
	≥5	3.174	3.014–3.343	1.201	1.118–1.291	3.759	3.573–3.954	1.362	1.267–1.465
Elixhauser comorbidity index	0	reference		reference		reference		reference	
	1	1.792	1.748–1.838	1.280	1.233–1.330	2.044	1.994–2.095	1.285	1.237–1.335
	2	2.368	2.304–2.433	1.604	1.532–1.679	2.771	2.701–2.843	1.583	1.512–1.657
	3	2.833	2.737–2.933	1.896	1.797–2.001	3.490	3.382–3.602	1.935	1.836–2.040
	4	3.454	3.290–3.626	2.296	2.150–2.452	3.946	3.767–4.133	2.192	2.053–2.339
	≥5	3.800	3.569–4.046	2.509	2.318–2.716	4.306	4.039–4.590	2.403	2.215–2.608

CI, confidence interval; HR, hazard ratio; LHUs, Local Health Units.

This research builds on a previous study about the effect of vertical integration on readmissions [10]. We extend previous research by illuminating that the risk of readmission varies across LHUs when other patient-level characteristics are considered. Whereas our previous research stressed a positive effect on decreasing the risk of readmission across LHUs [10], in this study a more modest effect was observed. To understand whether these differences were attributed to statistical model specifications, we applied the modeling of our previous research on this new dataset. Computed estimates for the risk of readmission were analogous to those previously reported [36]. Hence, we believe that differences between previous estimates of the risk of readmission and our current findings are to a large extent attributed to the inclusion of the number of chronic conditions and the Elixhauser comorbidity index. Given that LHU7 was not included in the previous study, we were not able to compare results.

Limitations

Our research relies on administrative data and used a retrospective cross-sectional study design, therefore it is limited in its ability to establish causality. Selection bias may have occurred with our choices for the control group, but a randomized control trial design was not feasible for the purpose of this study. We could not account for an extensive list of patient-level factors (e.g. education, income or community support), for these were not available in the Portuguese inpatient databases. Also, organizational-level effects captured by statistical models were limited to two years following vertical integration, when learning effects on vertical integration across LHUs were more intensive. Lastly, the selected model to identify readmissions and to predict an individual's risk of readmission may be subject to discussion. We chose to use the CMS' methodological approach for its discriminant power, international widespread use and dense discussion within the research community. Despite these limitations, this study can add new information to the debate on the effects of vertical integration on readmissions, with particular focus on the most vulnerable individuals such as those with multiple chronic conditions.

Conclusion

Our findings suggest mixed results: the risk of readmission decreased in four LHUs, but significantly only in two. Several challenges still have to be addressed to achieve a larger and long-lasting effect on decreasing 30-

day hospital readmissions. Hence, it is relevant to develop effective strategies at the hospital level, such as ensuring appropriate discharge planning, effective primary care follow-up after discharge and strengthened communication and collaboration between providers of different levels of care. Additional policies focusing on more vulnerable populations should be considered in combination with fair financial incentives. In addition, making information on risk-adjusted readmission rates publicly available, combined with other performance indicators that matter to citizens, may lead care providers to show greater interest in developing patient-centered strategies.

Finally, the success of the Portuguese vertical integration experience in the NHS cannot be assessed solely by its effects on readmissions. Instead, a wider multidimensional set of performance indicators should be considered, along with an analysis of case studies that further explore the efforts of each LHU to overcome barriers to effective care delivery in vertically integrated organizations.

Statement of Ethics

The Portuguese Central Administration for the Health System provided the administrative databases, which were pseudonymized and made available to NOVA National School of Public Health. The use of the databases was approved by the NOVA National School of Public Health. For this type of study formal consent is not required.

Disclosure Statement

The authors declare that they have no conflict of interest.

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