Universidade NOVA de Lisboa

Escola Nacional de Saúde Pública

Impact of vertical integration on the readmission of individuals with chronic conditions

Master in Health Management

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Lisbon, July 2016

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Dissertation presented to Escola Nacional de Saúde Pública in partial fulfilment of the requirements for the Degree of Master in Health Management, developed under the supervision of Professor Rui Santana and Professor Sílvia Lopes.

Lisbon, July 2016

ACKNOWLEDGMENTS

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The only true voyage of discovery, the only fountain of Eternal Youth, would be not to visit strange lands but to possess other eyes, to behold the universe through the eyes of another, of a hundred others, to behold the hundred universes that each of them beholds, that each of them is (…).

Proust, in *Remembrance of things past: The prisoner (Vol. 5)* (1923).

ABSTRACT

INTRODUCTION: Ageing populations and the increasing prevalence of multimorbidity are a challenge for healthcare delivery and health system design. Integrated care has been discussed as a solution to address these challenges. In Portugal, Local Health Units (LHU) promote vertical integration of healthcare, with one of the expected effects being a decrease of readmission rates in individuals with chronic conditions. Readmissions are frequently studied for its negative impacts on individuals, carers, and providers, with excessive unplanned readmission rates among hospitals being a sign of frail integrated care. Thus, we assume as the main aim of this study to assess the impact of vertical integration on the readmission of individuals with chronic conditions.

METHODS: A database including administrative data from 1 679 634 inpatient episodes from years 2002-14 was considered. We identified readmissions with the hospital-wide all-cause unplanned readmission measure methodology of Centers for Medicare and Medicaid Services. The considered outcome was 30-day hospital-wide all-cause unplanned readmissions (1: readmitted), and risk-standardized readmission ratio. Chronic conditions were identified from all diagnoses coded with International Classification of Diseases – 9th version – Clinical Modification codes (1: chronic). In order to assess the impact of LHU on the readmission of individuals with chronic conditions, we compared 30-day readmissions before and after the creation of each LHU. We used difference-in-differences technique to address our main aim. In addition, to understand the associations between individuals' risk factors and time to readmission, we developed a Cox regression model for LHU and control group.

RESULTS: Difference-in-differences results suggest that vertical integration promoted a decrease on risk-standardized readmission ratio in four LHU, but significant only in LHU 1. In addition, when analysed the individual risk of readmission we observed that it was reduced for four LHU, but only significantly for LHU 3 and LHU 5. A sensitivity analysis was performed for annual evolution of odds ratio of risk of readmission, and initial results were considered stable for most years. Cox regression results suggest that for LHU and control hospitals, female individuals were less at risk of readmission than men, the risk increased with increasing age and number of comorbidities. At LHU, we observed a decreased risk of readmission with increasing number of chronic conditions.

CONCLUSIONS: Individuals with chronic conditions faced higher risk of readmission, despite vertical integration phenomena. In order to promote better healthcare to these individuals, namely protecting them from readmission, healthcare organizations should develop integrated care pathways for the most prevalent chronic conditions on their catchment area, revise discharge processes, continuously evaluate health outcomes, and share best practices of integration involving community and other levels of care (namely palliative care).

KEYWORDS: Integrated healthcare; Vertical integration; Chronic conditions; Readmissions; Difference-in-differences.

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LIST OF ACRONYMS

ACSS – Portuguese Central Administration for Healthcare System

AHRQ – Agency for Healthcare Research and Quality

CCI – Chronic Condition Indicator

CCS – Condition Classification System

CMS – Centers for Medicare and Medicaid Services

DiD – Difference-in-differences

ICD-9-CM – International Classification of Diseases, 9th revision, Clinical Modification

LHU – Local Health Unit

NHS – National Health Service

OECD – Organization for Economic Co-operation and Development

SRR – Risk-Standardized hospital-wide 30-day Readmission Ratio

WHO – World Health Organization

INTRODUCTION

Healthcare systems sustainability is a global concern, aggravated by the demographical and epidemiological changes, and with the increase burden of disease and chronic conditions creating one of the biggest strain. Thus, these threats shape the way healthcare delivery is designed[1] and how healthcare organizations are managed.

Vertical integration of healthcare providers is a way to respond to these challenges, addressing differentiation and fragmentation, as well as the healthcare needs of individuals with chronic conditions and multi-comorbidities, since they require a consistent and long term care attention.[2] Furthermore, vertically integrated healthcare providers are expected to develop better transitions of care[3], with one of the estimated effects being a decrease on the readmission frequency of individuals with chronic conditions.

Because readmissions are costly[4] and threaten healthcare systems' sustainability, increase individuals' vulnerability and expose them to several hospital level risks[5], and being individuals with chronic conditions the ones who face higher likelihood of readmission, it is urgent to investigate if and how vertical integration is addressing these concerns.

In Portugal, vertical integrated care is materialized by Local Health Units (LHU) and arose from the expectation of effective coordination between primary and hospital care, in order to better respond to the needs of the population.[6,7] Since vertical integrated care approaches to healthcare are expected to decrease readmissions[8], we presume that LHU has that effect on individuals with chronic conditions. Evidence from other countries suggests a mixed impact regarding integrated healthcare and hospital readmission[9–14], thus we consider research over this topic essential for a better integrated care and centred on individuals' points of view and needs. In addition, in Portugal there is no study, as far as we know, that evaluated LHU effects over the readmission of individuals with chronic conditions. Thus, with this research we aim to bridge this gap.

This dissertation is organized in six chapters. On Chapter 1, we introduce a theoretical framework concerning integrated care, what has been done in Portugal regarding this organizational principle for healthcare delivery, the burden of chronic conditions, the importance of hospital readmissions as well as the effects of integrated care on the readmission of individuals with chronic conditions. On Chapter 2, we focus on the aims of the research, presenting the problem that configured the investigation and

a set of objectives proposed to be accomplished within this study. On Chapter 3, we present the methodology of the study, starting with the study design and the explanations for our choices. We also share information regarding data sources, criteria for inclusion and exclusion of observations, explanations for variables and a description of statistical analyses conducted. On Chapter 4, we present the major findings produced within this study. On Chapter 5, we provide a discussion of main findings with previous studies and theoretical framework regarding the three major vectors of this work: integrated care (with focus on vertical integration), chronic conditions and hospital-wide all-cause 30-day unplanned readmissions. We also present some of the limitations we had to face while developing this study, insights over further research and recommendations for the future. Finally, on Chapter 6, we summarize our work, and present final remarks.

CHAPTER 1

BACKGROUND

In Portugal, the population's life expectancy has been consecutively improving over the last few years.[15] However, when compared to other European countries, Portuguese men and women aged 65 and over, live fewer healthy years.[15] Thus, ageing populations[16,17], the prevalence of multimorbidity[17], and the current increasing pressure of burden of disease challenge healthcare systems[18,19] and the way healthcare delivery is designed[1]. Some authors[20] stress that the argument is not the ageing population but the underlying health burden of chronic conditions that created one the biggest strain on healthcare systems.

Throughout the years, there have been continuous political movements to reorganize the structure of healthcare delivery, with the aim of improving the quality of care and simultaneously make it more cost-effective. Thus, the National Health Service (NHS) sustainability is assumed as a difficult structural challenge, along with the transformation of the NHS towards a system where health promotion and disease prevention are the driving forces. Portuguese integrated care experiences, with horizontal and vertical integration phenomenon, are a sign of the efforts that materialize this healthcare policy.

1.1. INTEGRATED CARE AND THE PORTUGUESE EXPERIENCE

Shaw and co-authors[21] define integrated care as an organizational principle for care delivery, and integration as the methods, processes and models to achieve integrated care, as a managerial response to differentiation and fragmentation[22]. On this study we assume World Health Organization (WHO) definition of integrated health services as "the management and delivery of health services such that people receive a continuum of health promotion, disease prevention, diagnosis, treatment, disease-management, rehabilitation and palliative care services, through the different levels and sites of care within the health system, and according to their needs throughout the life course"[22, p49].

Minkman[19] states that the growing relevance of integrated care is related to the reshape of healthcare systems by: i) socio-demographic and epidemiological transitions; ii) the growing number of individuals with complex care needs with chronic conditions

and comorbidities; iii) engagement of individuals and caregivers in the treatment decision-making; iv) new professions arising from the demanding communications between specialists and generalists and; v) the complex and fragmented healthcare systems.

Integration can focus on primary and secondary care, but may also have a wider scope and involve social care[24], insurance or other human service systems as stated by Leutz[25]. The common focus of many integrated care approaches includes the support to individuals with chronic conditions to live more independently[11,26], with improvements to their care experience.

Vertical integration is one of the structural dimensions of integrated care.[27] This process can be characterized by the transformation of the elements of a particular organizational structure, giving rise to a new structure, involving new management relations, and communication flow responsibilities. Vertical integration is therefore an organizational conceptualization of a healthcare structure, which involves creating a single management entity, and at least two units providing healthcare at different levels of care. Santana[28] points out that the cumulative conditions for recognition of vertical integration are: i) the existence of a single entity responsible for health; ii) in a given geo-demographic space, well defined and limited; iii) serving a population covered by the entity; iv) with coordinated efforts among all healthcare units in the integrated care system.

There is a global shift concerning integrated care[19], being given more frequently visibility to the experiences in the U.S.A. and United Kingdom[29]. Despite the many integrated care approaches across the world, there is not just a single model that best fits integrated care needs. The development of integrated care services is a non-linear and dynamic process[19], requiring the system to foster an adaptive and transformative culture, and being promoted as an approach for improving accessibility, affordability, quality of care and effectiveness, with a special focus on people with complex needs[30–32]. For recognizing the frailties in developing integration across different providers, Goodwin and co-authors[33], through case studies, argue that the starting point to integrated care should be a clinical/service model designed to improve care instead of an organizational model with a pre-determined design.

Despite being a current theme in healthcare research[34], there is no widely accepted definition of integrated care[19,22,30,32,35] or a set of core factors that facilitate integrated care to be more person-centred. Hence, there is frequent confusion with

organizational structures and processes such as disease and case management with integrated care.[31] In addition, cultural contexts and settings configure integrated care definitions. This lack of focus of integrated care can make it difficult to implement and obtain desired outcomes, namely a decrease on the number of readmissions[36].

Portugal has been showing some legislative sensibility regarding care integration, some of it disruptive, attempting to adopt the best international practices (e.g., the first law of mental health, Law 2118/1963, 3 April).[37] The most recent Portuguese experience regarding vertically integrated care has begun in 1999, ahead of other European countries[13]. However, there is a lack of a systematic evaluation of its purpose as well as the dissemination of results and impacts.[8]

The Local Health Units (LHU) arose from the expectation of effective coordination between primary and secondary care, in order to better respond to the needs of the population.[6,7] LHU are responsible for the health of a population, providing healthcare under the coordinated management of a hospital (or hospitals, in the case of a hospital centre) and primary healthcare units.

In Table 1, we see that the first LHU was created in 1999 (LHU Matosinhos) by Decree-Law 207/99, 9 June[38], merging one hospital and 26 primary care providers, covering over 175 000 inhabitants. For eight more years, this was the only LHU. Only between 2007 and 2009 were created new LHU, providing integrated care for inhabitants from Alentejo, North, and central Portugal. In 2011 and 2012, two more LHU were created, one in the North another in Alentejo. Nowadays the LHU network provides healthcare for 1 145 904 inhabitants, around 11.6% of the Portuguese mainland population.

Table 1: Evolution and attributes of local health units (LHU) network.

LHU	Year	Health region	Number of providers		Population*	Legal framework
			Hospital	Primary care†		
Matosinhos	1999	North	1	26	175 321	DL 207/99, 9 June[38]
Norte Alentejo	2007	Alentejo	2	94	115 663	DL 50-B/2007, 28 February[39]
Alto Minho	2008	North	2	58	242 159	DL 183/2008, 4 September[40]
Baixo Alentejo	2008	Alentejo	2	83	124 690	
Guarda	2008	Centre	2	88	144 273	
Castelo Branco	2009	Centre	1	86	105 944	DL 318/2009, 2 November[41]
Nordeste	2011	North	3	98	140 440	DL 67/2011, 2 June[42]
Litoral Alentejano	2012	Alentejo	1	50	97 414	DL 238/2012, 31 October[43]

* Resident population by county in LHU's catchment area was retrieved from National Statistics Institute on May 2016. Last data update by June 16, 2015. † The number of primary care providers is the sum of health centres and their extensions, as well as family health units. Information retrieved from [44].

OECD[45] stresses that Portuguese healthcare needs to evolve towards a more integrated approach, increasing and deepening relations among the various levels of care, including palliative care. To prevail the success and effectiveness of these movements, a reflection period is mandatory over the existing experiences of integrated care. However, there are only a few studies about this model of organization and management of healthcare (e.g., 15, 16, and 36). There is a lack of evidence regarding economic, financial and covered population's health outcomes, namely on individuals with complex needs of care like those with (multiple) chronic conditions.

1.2. CHRONIC CONDITIONS

Chronic conditions refer to health conditions that persist across time (for at least 12 months), that require on-going healthcare interventions, either medical products, services or special equipment, and/or places limitations on self-care, independent living, and social interactions.[47] This definition also includes non-communicable diseases, mental disorders, some communicable conditions and on-going physical impairments.[48]

The burden of chronic conditions has been globally underestimated by society, political and health systems regarding its transversal effects.[49,50] Chronicity is a challenge to all developed[51,52] and developing countries[50], especially because a source of the rise in cost for healthcare systems comes from the fact individuals with chronic conditions receive fragmented care.[20,53,54] Thus, international governments have committed to an integration of healthcare that specifically addresses the growing prevalence of chronic conditions in the population.[51,55,56] However the evidence of integrated interventions designed to address individuals with chronic conditions healthcare needs seems to be sparse and inconsistent.[57]

In Portugal, according to the WHO[58], the population aged between 30 and 70 years have a 12% probability of dying from one of the four major chronic conditions (cancer, diabetes, cardiovascular diseases or chronic respiratory diseases). Hence, more than half of the Portuguese population (54.8%) is at risk of premature mortality due to these non-communicable diseases. The WHO[58] estimates that 86% of the Portuguese deaths are explained by one or more chronic conditions, and according to 2012 information, about 97 000 deaths were due to, at least, one chronic condition. Cardiovascular diseases were responsible for 32% of all deaths, cancers by 28%, chronic respiratory diseases accounted for 6% of all deaths and diabetes by 5%.[58]

According to Anderson[49], the growing trend of the presence of chronic conditions on individuals' health illuminates less successful aspects in the evolution of health systems, historically centred in the treatment of infectious and acute diseases. Also, individuals with chronic conditions are more likely to experience hospital readmissions[53,59] since they are more vulnerable to the consequences of non-effective integrated care.

1.3. HOSPITAL READMISSIONS

Hospital readmission is considered as a new inpatient episode after an index admission (i.e., an initial hospital admission) within a given period. Thus, one's choice regarding time frame, or relations with the index admission (e.g., principal diagnosis) are crucial to define readmissions. Readmission, in the current study, is defined as a subsequent inpatient admission to any acute hospital for any condition that occurs within 30 days of the initial discharge date.

Readmissions are a complex organizational and clinical challenge since not all readmissions can be prevented. Readmissions can be grouped as planned/unplanned and if related or not to the index admission diagnosis.[60] Planned readmissions are not considered a sign of poor quality of care as they are identified on the discharge process and part of the individual's treatment. On the other hand, admission for acute conditions or complications are most likely not planned, thus a concern for healthcare systems and users[61]. Thus, reducing the volume of unplanned readmissions is a frequent strategy for improving the quality of healthcare. This research will focus on unplanned readmissions only.

An all-cause readmission measure stresses the fact that, from an individual perspective, a readmission, regardless the cause, is always an adverse event[62]. Individuals are more vulnerable when they are away from their home, family and communities, exposed to several hospital level risks, and vulnerable to the experience that Krumholz[5] dubbed the post-hospital syndrome.

The 30-day period for outcome measure is a much used benchmark value. It is more useful for evaluating the effectiveness of hospital discharge and post-acute period[63,64], even though some authors propose a time frame of three to seven days or a weighting scheme based on the days to readmission[65–67].

Some authors[65,68] stress that 30-day readmission measure association to hospital quality has not been clearly proved, mainly because there are unplanned readmissions considered unavoidable, for they go beyond hospital's scope of action (e.g., social and economic factors, home and community frailties or natural progression of disease)[69]. Also, van Walraven[68] stress a set of deficiencies regarding the utility of unplanned readmission measure as a healthcare quality indicator, focusing on health administrative databases and the potential to capture avoidable readmissions.

Despite the frailties reported to this measure, it is commonly used because 30 days is considered a clinically sensible time frame that can be strongly influenced by hospital care and the transition to the outpatient setting, as well as being a critical period for hospitals to collaborate with their communities in order to reduce readmissions.[4,70] Thus, a shorter time frame for readmission emphasises the importance of transition of care and individuals' suitability for discharge.

There are various interventions addressed to reduce hospital readmission, with different potential degrees of effectiveness.[71] One example are case management approaches with enhanced primary care access.[12] Another one refers to referral networks. The main goal is to promote a more comprehensive healthcare system, less fragmented, and with a deeper set of coordinated activities.[72] Logue and co-authors[73] highlight facilitating self-care, individuals' education about their condition and medications, assessing social frailties, and coordinated follow-up after discharge as common factor to these programs. Additionally, clarifying individuals discharge instruction is an activity that hospitals engage in to reduce readmissions[74,75] and address individuals' concerns such as feeling unprepared for discharge[62] or difficulties adhering to the discharge medication[76]. There is evidence that involving primary care teams in the discharge planning by designing a multicomponent person-centred intervention has significant impact on decreasing the number of readmissions.[12] Usually, successful interventions for reducing readmission rates are a composite of different interventions[36,77] targeting multidimensional risk factors present in discharged individuals[3]. Thus, multidimensional interventions require substantial resources for planning, implementation, and monitoring[78], that may represent a challenge for management and care teams.

Transitional care interventions are focused on preventing repeated and avoidable readmissions, and poor and negative health outcomes after a hospital discharge.[29] Transitions between hospital and primary care settings are usually more emphasised.

However, transitions to nursing home[79] or palliative care[80] are also important for decreasing readmissions.

The interventions to accomplish better health outcomes, namely fewer readmissions, are diverse and vary on intensity across transitional care. Rennke and colleagues[81] present transitional care strategies grouped as: i) pre-discharge interventions (e.g., assessment of risk for adverse events or readmission); ii) after discharge interventions (e.g., medication reconciliation after discharge) and; iii) bridging interventions, a composite of at least one pre- and post-discharge intervention. Verhaegh and co-authors[29] stress that these interventions should be initiated during hospital admission and continued after discharge, involving home visits, and telephone follow-up for a minimum period of one month, thus reducing readmissions.

Developing multidimensional transitions of care involves a great deal of time and human resources from care facilities, hence most transitions of care are directed at specific groups that face higher risk of readmission and would benefit more with these interventions (e.g., individuals with chronic conditions and/or with multi-comorbidities), and with greater effect on reducing readmission.[78]

1.4. INTEGRATED CARE EFFECTS ON READMISSIONS

A vertically integrated care approach to healthcare is expected to decrease the number of readmissions. It is also a way of assuming that there are modifiable factors driving readmission that could be targeted at a hospital level to reduce them[63], and promote a better continuum of care across providers at different levels. Thus, readmission rates reflect not only the quality of hospital care[82–84] but also factors in individuals' homes and communities[67,76,85] (e.g., there is evidence of positive association between the number of primary care physicians in a given population and readmission rates[86,87]).

Dorling and colleagues[11] stress that integrated care was associated with a 19% reduction on index admissions for individuals with chronic conditions, and a continuum culture between primary and secondary care had impact on decreasing hospital readmissions[12]. Polanco and co-authors[13] measured the impact of integrated care and highlight a rate reduction for hospital admissions and 30-day readmissions. For individuals with chronic conditions, results show a reduction in hospital admissions with little being mentioned regarding readmissions. On the other hand, other study[88] stated

that LHU have reduced the risk of 30-day readmission by the same diagnosis from 2008 to 2014 (odds ratio decreased from 1.03 to 0.98).

Despite there being efforts for a better vertically integrated care, results seem to be modest, with poor evidence concerning health outcomes improvements.[9,10] Evidence suggests mixed impacts regarding vertical integrated care and hospital readmission.[9–14] For example, Massachusetts General Care Management was able to improve physical functioning of individuals with multimorbidity, and to substantially reduce hospitalizations and emergency departments visits of individuals with ambulatory care sensitive conditions, but did not reduce readmission.[14]

In order to vertically integrated care produce effects on readmissions of individuals with chronic conditions, there has to be a more effective continuum of care among different levels of healthcare providers, namely primary and secondary level. Primary care assumes a relevant role in the coordination and integration of care with the main functions of being individuals' first contact with the health systems, continuity of care throughout time, comprehensiveness of services needed to serve a population healthcare needs and referring individuals both horizontally and vertically.[17] Thus, the quality and scope of primary care have an impact on integration of care, namely decreasing readmission.[56] However, Hesselink and co-authors[89] conducted a systematic review of the literature concerning hospital and primary care transitions and did not found robust evidence of integrated care decreasing readmissions, in particular in individuals with chronic conditions.

Despite the mixed evidence of the effects of vertically integrated care on the readmission of individuals with chronic conditions, Leutz[25] stresses that not all individuals with chronic conditions need fully integrated care. Therefore, transitions between coordination or full integration of care should depend on the severity of the chronic condition[31] and existing comorbidities, showing the flexibility to address the best features of integration to the ones who need it the most.

In summary, new performance models are required to cope with all the challenges stated early on this chapter, while appealing to the rational use of resources and adoption of best practices. There is a movement to promote a culture of health[90], deepening the relationship between healthcare and a larger and broader network of partners, addressing the realities of individuals' lives that directly influence health outcomes and costs.

CHAPTER 2

RESEARCH AIMS

Readmissions are a topic that has been highly researched throughout the years and captured the attention of policy makers since late 1970's.[61] Nowadays the attention increased because of economic pressure to reduce the problem of unplanned readmissions, as well as a deeper concern about quality of life and care (e.g., readmission implies an increasing burden for individuals, families and caregivers[62]). Because of healthcare system frailties individuals are discharged sooner, increasing their responsibility on their treatment and transitions between healthcare providers.[56,91] Excessive unplanned readmission rates among hospitals could also be a sign of frail integrated care[63], thus this indicator is relevant to promote effectiveness and quality of care at a systematic level[92].

Our approach to the study of readmissions does not rely on hospital crude rates, but instead on adjusted to case mix and service mix, allowing for better comparisons between hospitals. Besides individuals' characteristics (e.g., chronicity and comorbidities) that may be associated with readmission, there are organizational features of the healthcare system itself that influence readmissions, namely vertically integrated care. For those reasons, and because there are still few studies regarding the impact of vertical integration on the quality of care[7,44,46,93], we chose to develop this study. As such, we assume as the main aim of this study to assess the impact of vertical integration on the readmission of individuals with chronic conditions. Moreover, the specific objectives of this study are:

- To describe 30-day readmission frequency in individuals with chronic conditions, from 2002 to 2014;
- To analyse the association between individuals' risk factors and readmission;
- To analyse the impact of vertical integration on the readmission rates and risk of readmission of individuals with chronic conditions.

CHAPTER 3

METHODOLOGY

3.1. STUDY DESIGN

This study was designed as a longitudinal and retrospective observational study. The event of interest was all unplanned readmissions within 30-day period following an index admission.

In order to assess the impact of vertical integration on the readmission of individuals with chronic conditions we compared 30-day unplanned readmissions before and after the creation of each LHU. We used administrative data to differentiate individuals' chronicity and comorbidity profiles, and to adjust statistical models more accurately to individuals' characteristics that are more likely to lead to an unplanned readmission.

We considered an eight-year time frame for each LHU, five years before integration and three post-integration (I-5 to I+2, being I the year when LHU was constituted). We considered this time frame so that we could study each LHU over the same period, despite the differences in the year of creation for each LHU. This way, and given the available data, we observed the evolution of each LHU on the period before and after its creation.

In a natural experiment one can make comparisons between groups (*treated* and the ones that did not receive treatment – *control*) if the treatment is exogenous and the two groups are comparable. This way one can ensure internal validity of a natural experiment.[94] The treatment group included seven out of eight LHU. We excluded LHU Matosinhos from the analysis because of its year of creation (1999), since there was no inpatient data available regarding the period before integration.

Difference-in-differences (DiD) is a widely used technique to assess the impact of real world policy or practice settings, comparing treated and control groups. In this case, the intervention is vertical integration. Using the DiD technique one can study how vertical integration influenced readmissions in individuals with chronic conditions, by comparing the differences occurred in the period pre- and post-vertical integration in

LHU and control group. Therefore, in order to address our main aim, DiD was the adequate technique.

In order to develop a better understanding of the readmission phenomena in LHU and control group, we studied the associations between individuals' risk factors and time to readmission. We conducted a Cox regression to analyse the influence of gender, age, number of chronic conditions and Elixhauser comorbidities on the risk of readmission in LHU and control group.

We performed DiD analyses considering two dependent variables: i) natural logarithm of the risk-standardized readmission ratio (SRR) and; ii) occurrence of readmission (risk of readmission).

We considered SRR, a hospital level measure, as dependent variable because it allowed studying the effects of vertical integration in a particular hospital's performance to be compared to an average hospital's performance, adjusting for discharge volume. We chose to use SRR methodology approach because it is public[95,96], there is a dense body of work of published literature regarding its utilization (e.g., 60, 65, and 66) and is still currently being discussed and challenged among researchers, policy makers, American hospitals and other stakeholders. On the other hand, the risk of readmission is an individual level measure that emphasises the probability of readmission given one's characteristics. Since the SRR is expected to be influenced by disruptions in the continuum of care, inadequate inpatient care and discharge planning, among other factors, we decided to study if vertical integration of healthcare had an impact on diminishing these effects on readmissions, thus reducing SRR. At an individual level, vertical integration is expected to decrease one's risk of readmission by promoting better continuum of care, considering a healthcare person-centred approach. Hence, we decided to study if vertical integration of healthcare had an impact on decreasing individuals' risk of readmission, given one's characteristics (age, principal diagnosis, presence of selected comorbidities, number of chronic conditions and comorbidities).

3.2. DATA SOURCE AND INCLUSION/EXCLUSION CRITERIA

The Portuguese Central Administration for Healthcare System (ACSS) provided the datasets. Datasets refer to administrative data from 2002 to 2014. These datasets include inpatient claims data with individual information regarding hospitalizations within public mainland hospitals, namely a unique encoded identifier, year and hospital

of treatment, gender, age, principal diagnosis, secondary diagnoses, procedures, type of admission, discharge date, length of stay, and discharge status.

All diagnoses and procedures were coded using International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM). Because the number of secondary diagnoses on these datasets varied in recent years, in order to get comparability among all datasets throughout 2002 to 2014, we only used the first 20 diagnoses (one principal diagnosis and 19 secondary diagnoses). Figure 1 presents the exclusion criteria applied, being selected 9 523 432 inpatient index admissions. From these, we selected for our analyses all episodes treated at LHU (n=845 275) and at control hospitals (n=834 359), totalizing 1 679 634 index admissions.

Episodes
(2002 to 2014)
n=20 152 283

Outpatient episodes
n=7 760 877

Unknown gender
n=176

Length of stay <0 or >365 days
n=1 241

Age <0 or >118 years
n=42

Error DRG (469 or 470)
n=7 644

Error in principal diagnosis
n=11

Specialized or low volume hospitals
n=132 514

Discharge status different than home
n=1 169 580

Episodes without at least 30 days post-discharge
n=911 485

Admissions for primary psychiatric diagnoses
n=154 993

Admissions for rehabilitation
n=3 430

Admissions for medical treatment of cancer
n=486 858

Final index admissions
n=9 523 432

Figure 1: Exclusion criteria applied to all episodes from Portuguese mainland public hospitals from 2002 to 2014.

3.3. CONTROL GROUP

In order to conduct the DiD analyses, a hospital control group was defined. Hospitals in this group were not vertically integrated, but were affected by the same external systemic effects that might have influence on readmissions.

The control group was derived using ACSS's benchmarking hospital groups (except psychiatric and public-private partnerships because these might be affected by different systemic effects). These benchmarking hospital groups were created by hierarchical clustering.[99]

Hospitals from the control group had to belong to benchmark group B or C, since all LHU were clustered between those groups. After the application of the exclusion criteria for hospitals, from benchmark group B we selected the three remaining hospitals, and from group C we randomly selected three.

3.4. VARIABLES

3.4.1. READMISSION

Readmissions were identified using Centers for Medicare and Medicaid Services (CMS) hospital-wide all-cause unplanned readmission measure[96] (1: readmission). First, we identified all index admissions, and selected those that could be analysed within a 30-day time frame. With the final set of index admissions, we identified episodes followed by an unplanned readmission and the ones that were planned. This study focuses on the 30-day unplanned readmissions.

3.4.2. COMORBIDITIES AND CHRONIC CONDITIONS

In order to better describe individuals' comorbidities and chronic conditions we used two measures: Quan's[100] updated version of Elixhauser comorbidity index[101] and Agency for Healthcare Research and Quality (AHRQ) chronic condition indicator[102]. Elixhauser comorbidity index is a method of categorising individuals' comorbidities and is widely used with administrative data to measure burden of disease. Only secondary diagnoses were included to compute the index. This index was designed to be used with specific ICD coding, therefore we used ICD-9-CM 5-digit codes to ascertain the presence of comorbidities (1: comorbidity present). We used AHRQ chronic condition indicator to

ascertain the presence of ICD-9-CM diagnoses codes considered as chronic conditions (1: chronic condition present).

We used these measures for its complementary information regarding individuals' health status. For instance, the drug abuse Elixhauser comorbidity group is considered a comorbidity for 292.x ICD-9-CM codes, but the code 292.0 (drug withdrawal syndrome) is considered a chronic condition while 292.11 (drug paranoid state) is not. Moreover, Elixhauser comorbidity index was reported with the ability to predict length of stay[103], and was also found significantly associated with healthcare expenditures and in-hospital mortality[104]. On the other hand, the chronic condition indicator works as a proxy to assess one's overall burden of chronic illness, engagement with the healthcare system and the total number of conditions being treated[105].

3.4.3. INDIVIDUAL RISK OF READMISSION

Individual risk of readmission was estimated using generalized linear mixed models at the specialty cohort level described elsewhere[96] (1: readmitted). For a given specialty cohort, we fitted a hierarchical logistic regression model to account for the natural clustering of observations within hospitals. From these models we obtained the risk of readmission for individual i at hospital j in year t as

$$RR_{ijt} = logit^{-1}(\mu + \beta * Z_{ij}),$$

where μ is the adjusted average outcome (being readmitted within 30-day time frame) over all hospitals and Z_{ij} a set of risk factors that are clinically relevant and strongly associated with the outcome (age, principal diagnosis and selected comorbidities). Age was treated as a continuous variable. For principal diagnosis, we used the AHRQ Condition Classification System (CCS) to group hospitalizations into clinical-coherent, mutually exclusive condition categories. Comorbid diseases were identified using the CMS Condition Category groups.

To reduce bias for the risk of readmission we fitted the model considering all episodes (n=9 523 432). The model performance, assessed by the use of c-statistic, the area under the receiver operating characteristic (ROC) curve, varied between 0.60 to 0.71, similar to the work by Horwitz and colleagues[96] (0.62 to 0.67).

3.4.4. Risk-standardized readmission ratio

The risk-standardized readmission ratio (SRR) reflects the number of readmission events at a hospital level, relative to the number of readmission events that would be expected based on average hospital performance. Therefore, this measure allows a particular hospital's performance to be compared to an average hospital's performance. A lower ratio (<1) stands for lower-than-expected readmission rate, and similarly a higher ratio (>1) stands for higher-than-expected readmission rate.

We chose to use as dependent variable the natural logarithm of SRR for three reasons: i) to reduce outlier noise; ii) to correct positive skewness, since SRR measure is always positive and; iii) to facilitate regression coefficients interpretation, i.e., marginal changes in the explanatory variables are interpreted in terms of percentage change in the dependent variable.

We provide further explanation regarding SRR in Appendix 1.

3.5. STATISTICAL ANALYSIS

3.5.1. Descriptive statistics

First we used frequencies analysis to describe LHU and control hospitals regarding gender, age groups (0-19; 20-44; 45-64; 65-84; and 85+), number of chronic conditions and comorbidities (0, 1, 2, 3, 4, and 5+), for the period 2002-14. We also listed selected principal diagnosis, based on the principal diagnoses that were simultaneously most frequent, with higher readmission frequency and readmission rate: diabetes mellitus with complications, congestive heart failure, pneumonia, acute bronchitis, chronic obstructive pulmonary disease and bronchiectasis, and urinary tract disease. This selection accounted for 10% of episodes and 25% of readmissions.

We computed the readmission rates for LHU and control hospitals and followed the same presentation scheme. In addition, we graphically analysed the evolution of crude readmission rates from 2002 to 2014, for LHU and control group. However, because the chronicity structure of our sample might affect the interpretation of the readmission rates, we also analysed the evolution of standardized readmission rates. For that, we applied a direct method of standardization, considering as standard population the total number of individuals distributed by the number of chronic conditions.

We also compared the variation of readmission rates throughout the years by number of chronic conditions, for LHU and control group, and compared readmission rate evolution with the national average readmission rate.

3.5.2. ASSOCIATIONS BETWEEN INDIVIDUALS' RISK FACTORS AND TIME TO READMISSION

We used a Cox regression (also known as proportional hazards regression analysis) to study the association between the time interval between admissions and possible covariates of a readmission. Various methodologies and techniques have been used for risk of readmission, with logistic and Cox regression being the most common methods used to identify risk factors.[106] The hazard function in this case refers to the probability that an individual will experience readmission within a 30-day time frame (risk of readmission at time t).

Covariates were gender, age group, number of chronic conditions, and number of Elixhauser comorbidities. All covariates association with time interval between admissions were assessed by a preliminary univariate Cox regression. Any covariate with $p < 0.1$ was used after in a multivariate Cox regression analysis. The multivariate model used a backward likelihood ratio stepwise data selection method. A cut-off value of $p < 0.05$ was applied to remove covariates from the final model. Verification of the proportional hazards assumption was based on a visual inspection of Kaplan-Meier plots.

These analyses were conducted separately for LHU and control group index admissions.

3.5.3. IMPACT OF VERTICAL INTEGRATION

3.5.3.1. Impact on the risk-standardized readmission ratio

The effect of vertical integration on the risk-standardized readmission ratio can be estimated by comparing the treatment and control group before and after integration. Let $ln(SRR_{jt})$ be the natural logarithm of the risk-standardized readmission ratio for hospital j at year t. Let I_{jt} be a binary variable taking on value 1 if hospital j at year t is LHU and 0 otherwise; τ_t a set of year dummies capturing period specific effects; π_0 is a constant term and ε_{jt} an idiosyncratic term. We considered the following model estimated by a pooled OLS:

$$\text{Model 1: } ln(SRR_{jt}) = \pi_0 + \delta I_{jt} + \tau_t + \epsilon_{jt}$$

The estimated coefficient δ stands for the DiD. To account for possible unobservable characteristics that might affect SRR over time, we adjusted standard errors by clustering at the hospital level. This mitigates bias over δ.

In order to account for time-invariant unobservable at hospital level we considered a set of hospital dummies (φ_{jt}). We also considered the average number of chronic conditions (Av_Chron_{jt}) and Elixhauser comorbidity index $(Av\_Elixhauser_{jt})$ for all individuals at hospital j as covariates thought to potentially influence readmission frequency, thus influencing SRR. Hence, the new model can be estimated as a fixed effects model:

$$\textbf{Model 2}: ln(SRR_{jt}) = \pi_0 + \delta I_{jt} + \tau_t + \varphi_{jt} + Av\_Chron_{jt} + Av\_Elixhauser_{jt} + \epsilon_{jt}$$

In order to relax the parallel trend assumption we used a DiD model with a differential trend model.[107] Incorporating the assumption we obtain the following fixed effects model:

$$\textbf{Model 3}: ln(SRR_{jt}) = \pi_0 + \delta I_{jt} + \varphi_{jt} + Av\_Chron_{jt} + Av\_Elixhauser_{jt} + \sum_{\lambda=2}^{T} \alpha_{j\tau} Year_\tau + \sum_{\lambda=2}^{T} \theta_{j\tau} Year_\tau I_{jt} + \epsilon_{jt}$$

The parallel trend assumption can be verified by testing the non-linear restriction $\frac{\sum_{\lambda=2}^{T} \theta_{j\tau}}{\sum_{\lambda=2}^{T} \alpha_{j\tau}} = 0$. Non-rejection of the null hypothesis of Wald's statistical test provides evidence in favour of the parallel trend assumption.

3.5.3.2. Impact on the risk of readmission

We used DiD technique to analyse the effects of vertical integration on the risk of readmission. We considered an unconditional logit model with fixed effects using dummy variables. There is still discussion regarding the use of dummy variables similarly as fixed effects. Greene[108] states that bias in estimators is large when number of years of data is small. Because we have a large number of observations per hospital and the number of years considered in this analysis for each LHU is T=8, according to Coupé[109], bias in the unconditional estimator is small and, for the purpose of our research we find it acceptable.

Let the dependent variable Y_{ijt} be a binary variable for episode i in hospital j at year t, assuming value 1 if it is a readmission episode and 0 otherwise. Let I_{jt} be a binary

variable taking on value 1 if hospital j at year t is LHU and 0 otherwise; $Post_{ijt}$ takes value 1 if admission of individual i occurred in hospital j in the year post-integration and 0 otherwise; $Treat_{jit}$ takes value 1 if admission happened in a LHU; τ_t is a set of year dummies capturing period specific effects; RR_{ijt} is the individual risk of readmission for individual i admitted in hospital j in year t, computed through a logistic generalized linear mixed model as discussed by Horwitz and colleagues[96]; π_0 is a constant term and ε_{ijt} an idiosyncratic term. The Model 1 estimated δ coefficient stands for the DiD. To account for possible unobservable characteristics that might affect risk of readmission over time, we adjusted standard errors by clustering at the hospital level to mitigate bias over δ.

$$\textbf{Model 1: } logit[Prob(Y_{ijt} = 1)] = \pi_0 + \delta I_{ijt} + \gamma Post_{ijt} + \beta Treat_{jit} + \tau_{jt} + RR_{ijt} + \epsilon_{ijt}$$

We considered a set of hospital dummies (φ_{jt}) to account for time-invariant unobservables at hospital level. We also considered the number of chronic conditions $(Chron_{ijt})$ and the Elixhauser comorbidity index $(Elixhauser_{ijt})$ for each index admission at hospital j as covariates thought to potentially influence risk of readmission. Hence, the new model can be estimated as a "fixed effects" unconditional logit model:

$$\textbf{Model 2}: logit[Prob(Y_{ijt} = 1)] = \pi_0 + \delta I_{ijt} + \gamma Post_{ijt} + \beta Treat_{jit} + \tau_{jt} + \varphi_{jt} + Chron_{ijt} + Elixhauser_{ijt} + RR_{ijt} + \epsilon_{ijt}$$

We used Wagstaff and Moreno-Serra's differential trend model[107] in order to relax the parallel trend assumption. Incorporating this assumption in the model, we obtained the following:

$$\textbf{Model 3}: logit[Prob(Y_{ijt} = 1)] = \pi_0 + \delta I_{ijt} + \gamma Post_{ijt} + \beta Treat_{jit} + \varphi_{jt} + Chron_{ijt} +$$
$$+ Elixhauser_{ijt} + RR_{ijt} + \sum_{\lambda=2}^{T} \alpha_{j\tau} Year_\tau + \sum_{\lambda=2}^{T} \theta_{j\tau} Year_\tau I_{ijt} + \epsilon_{ijt}$$

The parallel trend assumption can be verified by testing the non-linear restriction $\frac{\sum_{\lambda=2}^{T} \theta_{j\tau}}{\sum_{\lambda=2}^{T} \alpha_{j\tau}} = 0$. Non-rejection of the null hypothesis of Wald's statistical test provides evidence in favour of the parallel trend assumption.

We also developed a model that specifies each year's impact. In this case, because we have the effect of a treatment over different periods, Autor[110] states that it is suitable

to interact the treatment variable with time dummies. Let D_{jt} be a treated/control dummy equal to 1 if hospital j is in the treatment group and 0 otherwise. Then we construct Model 4 as:

$$\textbf{Model 4}: logit\left[Prob\left(Y_{ijt} = 1\right)\right] = \pi_0 + \sum_{k=-5}^{2} \delta_k D_{jt} + \tau_t + \varphi_{jt} + Chron_{jt} + Elixhauser_{jt} + RR_{ijt} + \epsilon_{ijt}$$

All time dummies interacted with D_{jt} are expressed relatively to the omitted time period which serves as baseline (year I-5), thus only years I-4 to I+2 will be presented (being I the year when LHU was created). It is possible to see how the effect varies over time, if it stays constant, decreases or increases by analysing δ_0, δ_1, and δ_2.

3.5.4. SENSITIVITY ANALYSIS

We recalculated DiD for risk of readmission under an alternative constitution of the control group to determine the impact of control group choice. This new control group accounted for hospital's organizational evolution between the period of 2002-14. We excluded all specialized and teaching hospitals. We compared the odds ratios results for each LHU against the new control group with those obtained with the initial control group.

We considered that the previous result was *stable* when there was less than 5% difference between odds ratios results for the same period.

The generalized linear mixed models to compute individual risk of readmission were run using SAS University Edition. The Cox regressions were performed using IBM SPSS software version 23 and the DiD analyses were performed using Stata software (v. 13).

CHAPTER 4

RESULTS

4.1. CHARACTERISTICS OF THE SAMPLE

Our sample had 1 679 634 index admissions (Table 2). The sample was evenly distributed, with LHU accounting for 50.3% of index admissions. Index admissions from female individuals were more frequent on both LHU and control group (55.8% and 57.1%). Individuals with admission at LHU were older compared to those from control group. The average age for LHU individuals was 51.3±28.4 years and for control group 48.5±28.9. The distribution of number of chronic conditions and comorbidities was similar in LHU and control hospitals.

Pneumonia was the most prevalent principal diagnosis in LHU and control group hospitals (4.4% in LHU and 4.7% in control group).

Table 2: Characteristics of the sample by gender, age group, number of chronic conditions, Elixhauser comorbidity index, and selected principal diagnosis, in the period 2002-2014, for treatment (LHU) and control group.

	Total		LHU		Control group	
	N	%	N	%	N	%
	1 679 634	100.0%	845 275	100.0%	834 359	100.0%
Gender						
Female	947 826	56.4%	471 566	55.8%	476 260	57.1%
Male	731 808	43.6%	373 709	44.2%	358 099	42.9%
Age						
0 - 19	362 884	21.6%	171 594	20.3%	191 290	22.9%
20 - 44	308 598	18.4%	148 511	17.6%	160 087	19.2%
45 - 64	319 657	19.0%	159 725	18.9%	159 932	19.2%
65 - 84	555 524	33.1%	295 788	35.0%	259 736	31.1%
85+	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%

	Total		LHU		Control group	
	N	**%**	**N**	**%**	**N**	**%**
	1 679 634	100.0%	845 275	100.0%	834 359	100.0%
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%
Condition specific indicator (AHRQ CCS)						
Diabetes mellitus with complications	23 107	1.4%	13 498	1.6%	9 609	1.2%
Congestive heart failure; nonhypertensive	36 821	2.2%	16 643	2.0%	20 178	2.4%
Pneumonia	76 933	4.6%	37 594	4.4%	39 339	4.7%
Acute bronchitis	25 293	1.5%	10 619	1.3%	14 674	1.8%
Chronic obstructive pulmonary disease and bronchiectasis	22 372	1.3%	11 354	1.3%	11 018	1.3%
Urinary tract disease	35 464	2.1%	14 261	1.7%	21 203	2.5%

4.1.1. READMISSION RATES BY SAMPLE'S CHARACTERISTICS

In Table 3, we observe that hospitals from the control group had higher readmission rate (4.8% *vs* 5.3%). Male individuals faced higher readmission rates (5.2% in LHU and 6.0% in control hospitals). Readmission rates increased throughout older age groups, with higher readmission rates in the control group (e.g., individuals aged 65-84 had a readmission rate of 6.3% in LHU and 7.6% in control hospitals). The readmission rates increased with increasing number of chronic conditions, with higher rates for hospitals from the control group. The same situation was observed with increasing number of comorbidities. Chronic obstructive pulmonary disease and bronchiectasis were the conditions with higher readmission rate in LHU (12.4%) followed by congestive heart failure (10.5%). For the control hospitals, the same diseases were the ones with higher readmission rates (13.2% and 13.3% respectively).

Table 3: Readmission rates by gender, age group, number of chronic conditions, Elixhauser comorbidity index, and selected principal diagnosis, in the period 2002-2014, for treatment (LHU) and control group.

	Total		LHU		Control group	
	N	**% Total**	**N**	**% Total**	**N**	**% Total**
	85 385	5.1%	40 779	4.8%	44 606	5.3%
Gender						
Female	44 302	4.7%	21 290	4.5%	23 012	4.8%
Male	41 083	5.6%	19 489	5.2%	21 594	6.0%
Age						
0 - 19	12 768	3.5%	5 583	3.3%	7 185	3.8%
20 - 44	8 904	2.9%	4 627	3.1%	4 277	2.7%
45 - 64	11 763	3.7%	5 697	3.6%	6 066	3.8%
65 - 84	38 521	6.9%	18 720	6.3%	19 801	7.6%
85+	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%
Condition specific indicator (AHRQ CCS)						
Diabetes mellitus with complications	2 047	8.9%	1 029	7.6%	1 018	10.6%
Congestive heart failure; nonhypertensive	4 435	12.0%	1 745	10.5%	2 690	13.3%
Pneumonia	7 121	9.3%	3 169	8.4%	3 952	10.0%
Acute bronchitis	2 709	10.7%	1 088	10.2%	1 621	11.0%
Chronic obstructive pulmonary disease and bronchiectasis	2 856	12.8%	1 405	12.4%	1 451	13.2%
Urinary tract disease	3 578	10.1%	1 331	9.3%	2 247	10.6%

4.1.2. EVOLUTION OF READMISSION RATES

In Figure 2, we present the evolution of readmission rates from 2002 to 2014, for LHU and control group. The evolution of crude readmission rate, and standardized readmission rate considering the distribution of the number of chronic conditions in each group, presented the same pattern.

When compared to LHU, the control group presented higher readmission rates throughout the years, but more emphasised since 2007. In both groups, readmission rates were increasing since 2011. In 2014, the standardized readmission rate for LHU was 5.2% and for the control group was 6.3%.
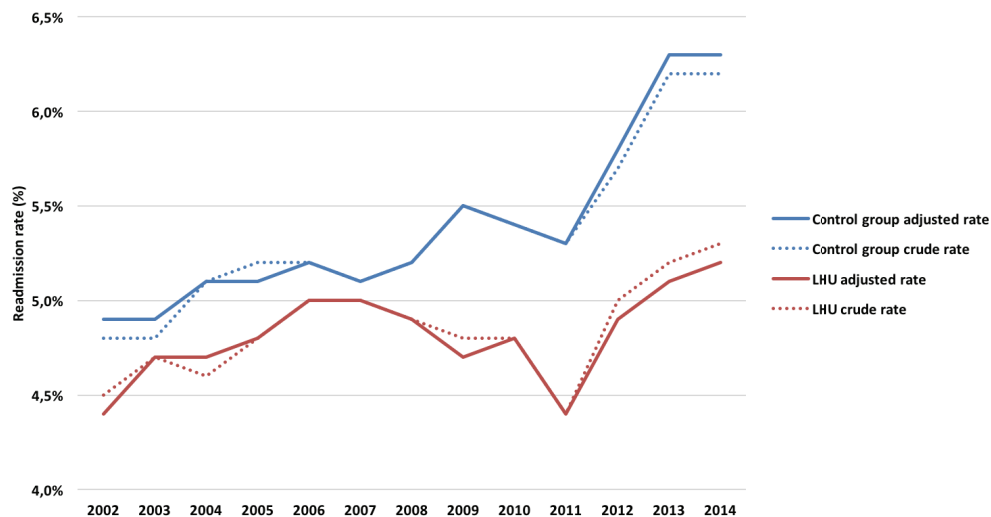
Figure 2: Evolution of crude and standardized readmission rates (%) from 2002 to 2014, for LHU and control group.

We analysed the evolution of crude readmission rates from 2002 to 2014 for LHU and control group, considering the number of chronic conditions (Figure 3). For individuals with no chronic conditions, readmission rates in LHU and control hospitals were similar, between 3% and 4%, and lower than national readmission rate in every year. For individuals with at least one chronic condition, readmission rates were higher than national readmission rate, and after 2003 readmission rates were higher in control hospitals, with a slight increase trend, while for LHU there was a decreasing trend. For individuals with two chronic conditions, for the past years, readmission rates stabilized around 7% in LHU, and 9% for control group. In the case of individuals with three chronic conditions, the scenario was very similar, with increasing gap between LHU and control group. For individuals with four chronic conditions, the control group had higher readmission rates in all years, stabilizing around 11% since 2011. For these individuals, readmission rates from the LHU group had an irregular pattern, stabilizing at around 8%. Finally, for individuals with five or more chronic conditions, the readmission rates were evidently higher when compared with individuals with fewer chronic conditions. In addition, the evolution of readmission rates was more irregular for these individuals, stabilizing for both groups since 2012 (around 10% for LHU and 12% for control group).
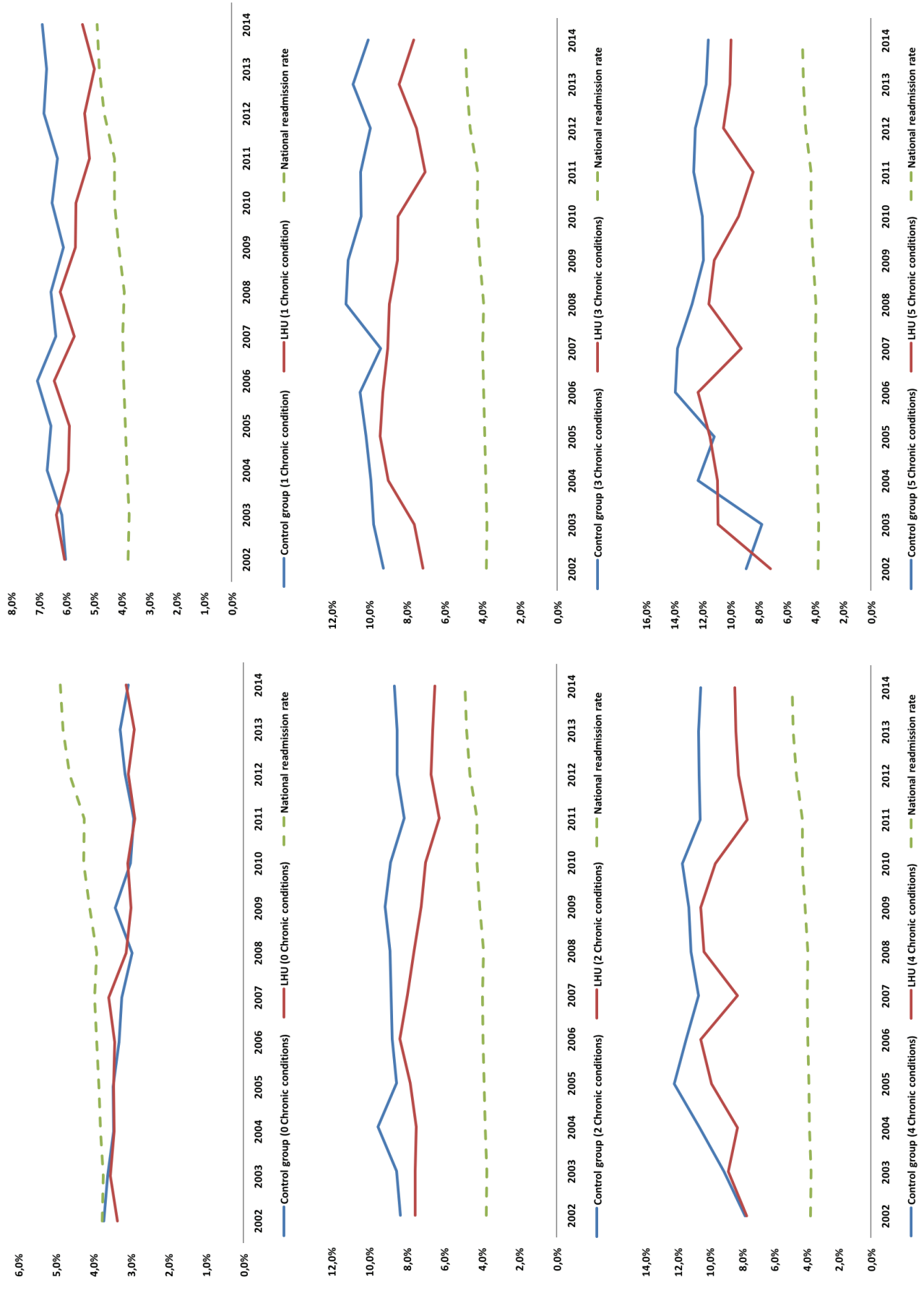
Figure 3: Readmission rates (%) from 2002 to 2014, by number of chronic conditions, for LHU and control group.

4.2. ASSOCIATIONS BETWEEN INDIVIDUALS' RISK FACTORS AND TIME TO READMISSION

Time to readmission had a similar pattern in LHU and in the control group (median time to readmission was 10 days). Thus, to develop a better understanding on how risk factors influenced time to readmission, we used a Cox regression. With this analysis, we determined the association between the time interval between admissions and possible covariates thought to influence readmission. Hence, the time variable considered days until readmission, or days of follow-up (30 days maximum), and the status variable considered if readmission occurred in a 30-day period. If not, the episode was censored. The covariates were gender, age group, number of chronic conditions, and number of comorbidities. This analysis was conducted separately for LHU and control group.

The approach we considered by using Cox regression not only takes readmission into consideration but also the time to readmission, providing a deeper understanding than that offered by logistic regression. In Table 4 we present the number of index admissions in each covariate.

Table 4: Frequency of index admissions and readmissions for LHU and control group by gender, age group, number of chronic conditions, and Elixhauser comorbidity index.

| | | LOCAL HEALTH UNITS | | | | CONTROL GROUP | | | |
| | | Study cases | | Readmitted cases | | Study cases | | Readmitted cases | |
Covariate	Subgroup	N	%	N	%	N	%	N	%
Gender	Male	373 709	44.2%	19 489	47.8%	358 099	42.9%	21 594	48.4%
	Female	471 566	55.8%	21 290	52.2%	476 260	57.1%	23 012	51.6%
Age	0 - 19	171 594	20.3%	5 583	13.7%	191 290	22.9%	7 185	16.1%
	20 - 44	148 511	17.6%	4 627	11.3%	160 087	19.2%	4 277	9.6%
	45 - 64	159 725	18.9%	5 697	14.0%	159 932	19.2%	6 066	13.6%
	65 - 84	295 788	35.0%	18 720	45.9%	259 736	31.1%	19 801	44.4%
	85+	69 657	8.2%	6 152	15.1%	63 314	7.6%	7 277	16.3%
Number of chronic conditions	0	498 858	59.0%	16 299	40.0%	498 776	59.8%	16 474	36.9%
	1	143 726	17.0%	8 322	20.4%	138 803	16.6%	9 045	20.3%
	2	99 850	11.8%	7 230	17.7%	96 886	11.6%	8 434	18.9%
	3	60 780	7.2%	5 007	12.3%	59 857	7.2%	6 165	13.8%
	4	26 437	3.1%	2 349	5.8%	26 249	3.1%	2 838	6.4%
	5+	15 624	1.8%	1 572	3.9%	13 788	1.7%	1 650	3.7%

		LOCAL HEALTH UNITS				CONTROL GROUP			
		Study cases		Readmitted cases		Study cases		Readmitted cases	
Covariate	Subgroup	N	%	N	%	N	%	N	%
Elixhauser comorbidity index	0	534 957	63.3%	17 906	43.9%	534 865	64.1%	18 342	41.1%
	1	151 269	17.9%	8 973	22.0%	142 302	17.1%	9 825	22.0%
	2	92 403	10.9%	7 182	17.6%	92 411	11.1%	8 556	19.2%
	3	42 128	5.0%	3 892	9.5%	42 526	5.1%	4 916	11.0%
	4	16 045	1.9%	1 791	4.4%	15 254	1.8%	1 979	4.4%
	5+	8 473	1.0%	1 035	2.5%	7 001	0.8%	988	2.2%

We conducted a preliminary Cox regression analysis to assess the association of the covariates with readmission. This analysis revealed that all covariates could be significant risk factors associated with readmission, thus all were considered in a multivariate Cox regression. Table 5 shows the results of unadjusted hazard ratio that provide the association of the lone covariate with time to readmission, and the results of the multivariate Cox regression model which we termed adjusted hazard ratio.

The unadjusted hazard ratio showed increased likelihood of readmission for older age groups, increasing number of chronic conditions and comorbidities, and a decreased likelihood of readmission for female individuals. Despite LHU and control group presented the same pattern of unadjusted hazard ratio, data suggests that LHU present a decreased risk of readmission for individuals with most chronic conditions and comorbidities when compared to control group.

The multivariate Cox regression models revealed that all covariates were significant predictors for readmission, both in LHU and control group. We observed similar risk patterns in both groups regarding gender and age. Female individuals had a decreased likelihood of readmission when compared to men, with control group presenting a better hazard ratio [LHU: 0.906 (0.889 – 0.924) and Control group: 0.861 (0.845 – 0.878)]. The risk of readmission increased throughout age groups, being consistent with unadjusted hazard ratio (e.g., individuals aged 85+ had an increased likelihood of readmission 1.716 times higher than those aged 0-19 in LHU, and 1.755 in the control group). The adjusted hazard ratio in LHU decreased with increasing number of chronic conditions, contrasting with the pattern for unadjusted hazard ratios. In the control group, individuals with two chronic conditions were the ones with higher likelihood of readmission (HR 1.472; 95% CI: 1.398 – 1.549) and the ones with five or more chronic conditions presented reduced risk of readmission (HR 1.362; 95% CI: 1.267

– 1.465). The increased number of comorbidities represented increasing risk of readmission, both at univariate and multivariate models. Individuals with five or more comorbidities in LHU faced a likelihood of readmission 2.509 times higher than those that had no comorbidities. In the control group, the likelihood of readmission of these individuals with multiple comorbidities were 2.403 times higher than reference category.

Table 5: Multivariate Cox regression for LHU and control group index admissions.

Covariate	Scoring	LOCAL HEALTH UNITS				CONTROL GROUP			
		Unadjusted hazard ratio	(95% CI)	Adjusted hazard ratio	(95% CI)	Unadjusted hazard ratio	(95% CI)	Adjusted hazard ratio	(95% CI)
Gender	0: Male	(Reference)		(Reference)		(Reference)		(Reference)	
	1: Female	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	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)

4.3. IMPACT OF VERTICAL INTEGRATION

4.3.1. READMISSION RATES BEFORE AND AFTER VERTICAL INTEGRATION

We analysed crude readmission rates for LHU and control group, before and after vertical integration, for the group of individuals with no chronic conditions, with one to three chronic conditions, and with more than three chronic conditions (Figure 4). Overall, data suggests the same decreasing pattern for LHU and control group for individuals with no chronic conditions. For individuals with chronic conditions, we obtained mixed results, specifically for the individuals with more than three chronic conditions.

For individuals with no chronic conditions, readmission rates faced a reduction in all LHU after vertical integration, being more expressive in LHU 1 (-0.8%). The same decreasing pattern occurred in the control group.

For individuals with one to three chronic conditions, most of LHU decreased readmission rates after vertical integration, with LHU 5 decreasing by -0.9% and LHU1, LHU 6, and LHU 7 decreasing -0.5%. Only LHU 4 experienced an increase on readmission rates (1.4%). The control group faced an increase in readmission rates for these individuals.

For the individuals with more than three chronic conditions, data suggests mixed results. While LHU 1, LHU 4, and LHU 6 increased the readmission rate after vertical integration, the others were able to decrease. The decrease was most expressive in LHU 3 and LHU 5 (-1.8%). The control group in the period after the creation of LHU 3, LHU 4, and LHU 7 also experienced an effect of reduction on the readmission rates.
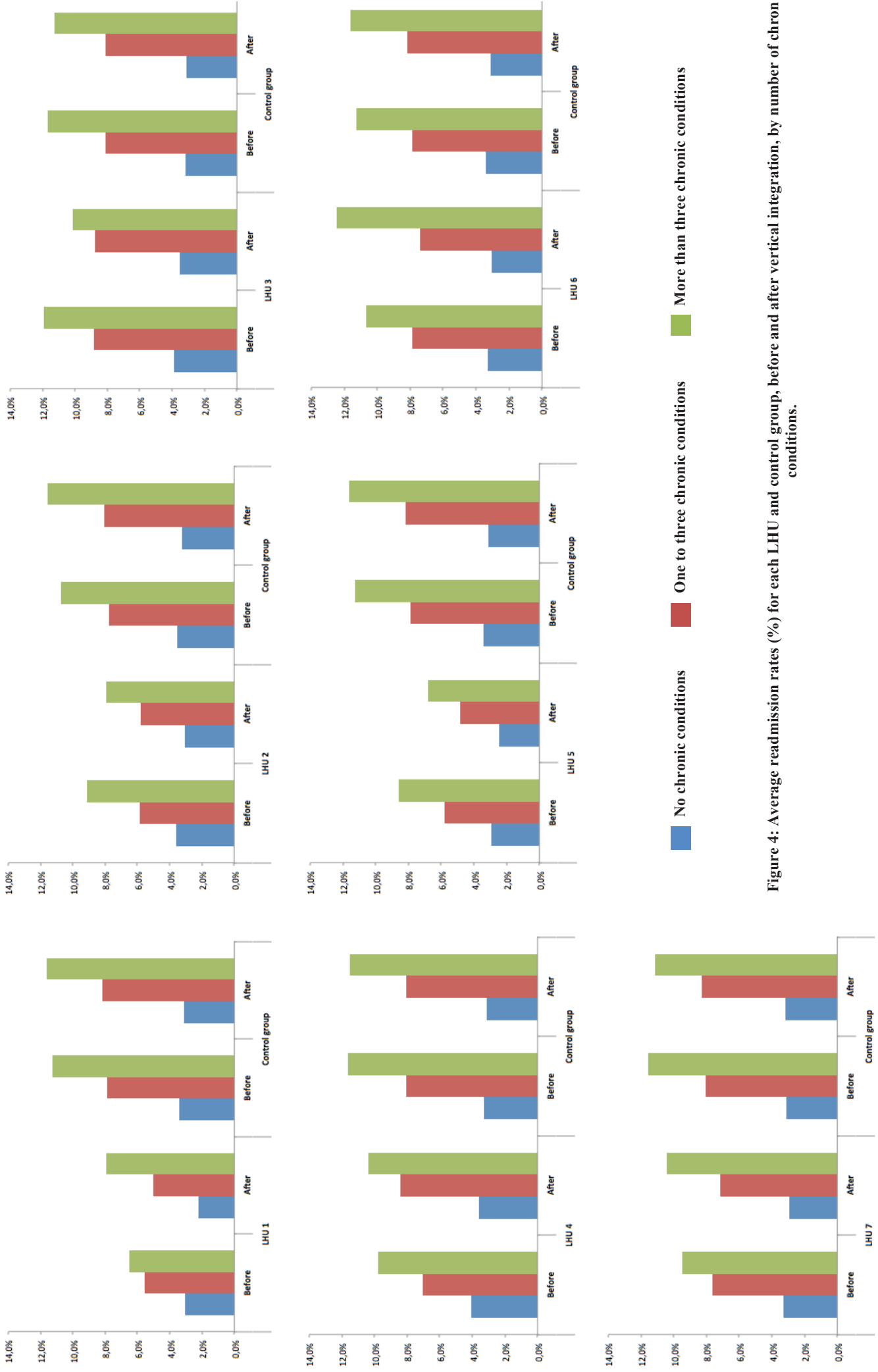
Figure 4: Average readmission rates (%) for each LHU and control group, before and after vertical integration, by number of chron conditions.

4.3.2. IMPACT OF VERTICAL INTEGRATION ON THE RISK-STANDARDIZED READMISSION RATIO

We computed the SRR for LHU and control group in the period 2002 to 2014 (Figure 5). For all years, the control group presented a higher SRR than LHU. From 2007 to 2010, LHU experienced a high decrease of SRR. Later in the control group, from 2009 to 2011, we observed the same effect.
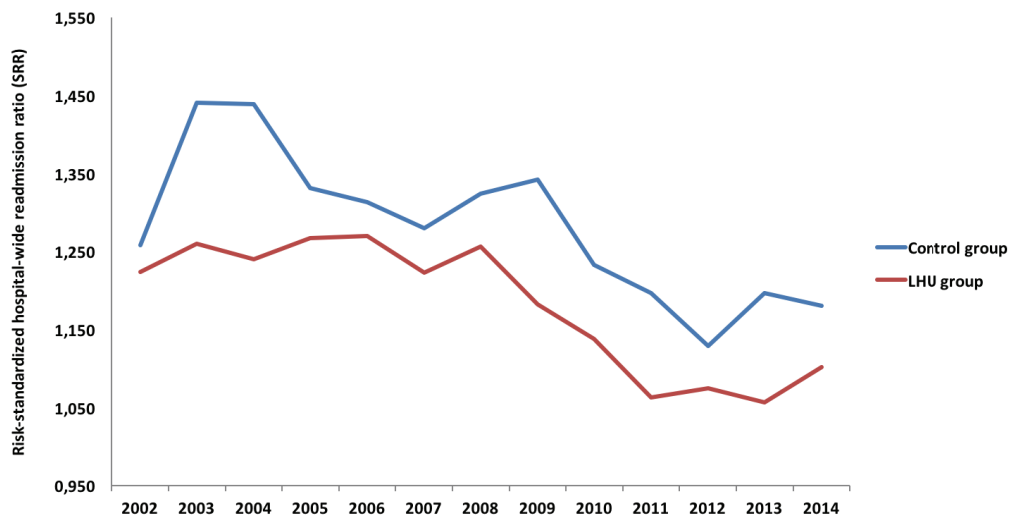
Figure 5: Risk-standardized readmission ratio (SRR) for LHU and control group in the period 2002-2014.

We performed DiD models with different specifications with natural logarithm of risk-standardized readmission ratio as dependent variable. In the last model we also ran a Wald test to check the parallel trend assumption for DiD (Table 6). For LHU 1, vertical integration has promoted a decrease in SRR, consistent with all three models. The result for LHU 2 shows a decrease in SRR in model 1 and 2, but an increase in model 3. However, the coefficient from model 3 belongs to the 95% confidence interval of model 2. The Wald test was significant, therefore parallel trend assumption cannot be assured, and one cannot attribute these results solely to vertical integration.

There is evidence that vertical integration promoted a 9.4% increase in SRR for LHU 3, but it was not significantly different from the control group. For LHU 4, LHU 5 and LHU 6, we observed a reduction of SRR varying from -4.8% to -7.2%, but without statistical significance, meaning there is no significant differences in risk-standardized readmission ratio between the LHU and the control group in the period pre- and post-integration. For LHU 7, the results show an increase of 23.4% of SRR in model 3, but this was not statistically significant.

Table 6: Difference-in-differences models for risk-standardized readmission ratio for each LHU compared to the control group, in the period I-5 to I+2.

	Model 1		Model 2		Model 3		Specification test	
	Coefficient (95% CI)	R^2	Coefficient (95% CI)	R^2	Coefficient (95% CI)	R^2	Wald test	p-value
LHU 1	- 29.3% (-41.0% ; -17.6%)	0.319	- 19.6% (-31.8% ; -7.4%)	0.798	- 30.8% (-45.1% ; -16.4%)	0.817	0.00	0.983
LHU 2	- 17.3% (-29.8% ; -4.8%)	0.193	- 4.7% (-15.5% ; 6.0%)	0.787	4.7% (-16.5% ; 25.9%)	0.794	5.30	0.021
LHU 3	12.8% (1.4% ; 24.3%)	0.232	6.9% (-4.3% ; 18.1%)	0.727	9.4% (-9.8% ; 28.6%)	0.743	0.32	0.571
LHU 4	10.3% (-0.1% ; 20.7%)	0.269	1.2% (-4.9% ; 7.3%)	0.792	- 4.8% (-18.1% ; 8.6%)	0.800	0.69	0.406
LHU 5	- 32.0% (-43.8% ; -20.3%)	0.297	- 7.8% (-17.3% ; 1.7%)	0.829	- 3.4% (-14.5% ; 7.8%)	0.831	0.11	0.742
LHU 6	3.0% (-8.7% ; 14.7%)	0.145	- 2.6% (-17.3% ; 12.1%)	0.694	- 7.2% (-24.2% ; 9.9%)	0.718	0.00	0.964
LHU 7	- 0.2% (-13.9% ; 13.5%)	0.194	14.6% (-7.3% ; 36.6%)	0.677	23.4% (-3.2% ; 50.0%)	0.684	0.57	0.450

4.3.3. IMPACT OF VERTICAL INTEGRATION ON THE RISK OF READMISSION

We performed a logistic regression to study DiD of risk of readmission in LHU and in the control group. In Table 7, we summarize the results for the three different models specified. In the last model we conducted a Wald test to check for the DiD parallel trend assumption.

For LHU 2 and LHU 4, the Wald test was significant, meaning that the effects observed in model 3 (despite being significant or not) cannot be solely attributed to vertical integration. Other factors could have happened that contributed to these results, and were not captured by the model specification.

The LHU 1 and control hospitals had a total of 600 086 index admissions, being 69 725 from LHU 1. Model 3 suggested a higher risk of readmission for LHU 1 when compared to the control group (OR 1.017; 95% CI: 0.940 – 1.101). For LHU 2, model 3 suggested a decrease in the risk of readmission (OR 0.991; 95% CI: 0.952 – 1.032). Although the result was not significant for model 3, model 2 suggested the same decrease in the risk of readmission but with statistical significance. For LHU 3, all models suggested that vertical integration promoted a decrease in the risk of readmission when compared to the control group. Model 3 suggested an odds ratio of 0.911 (95% CI: 0.837 – 0.991). For LHU 4, all models indicated a higher risk of readmission despite vertical

integration, but only model 3 was statistically significant (OR 1.240; 95% CI: 1.149 – 1.338). However, the parallel trend assumption was not verified, thus results should be interpreted with caution. LHU 5 performed similarly in all three models. Results suggest that integration promoted a significant decrease in the risk of readmission (OR 0.860; 95% CI: 0.790 – 0.936). For LHU 6, model 1 and model 2 showed a decrease in the risk of readmission, but none with statistical significance. Model 3 suggested an odds ratio for risk of readmission of 1.076 (0.992 – 1.166). Lastly, LHU 7 performed similarly in the three models, all suggesting a decreased risk of readmission. The parallel trend assumption was confirmed by Wald's test of significance, thus we can state that there is no statistical evidence that vertical integration promoted a decrease in the risk of readmission, with LHU 7 performing better than the control group but without statistical significance.

Table 7: Difference-in-differences models for risk of readmission for each LHU compared to the control group, in the period I-5 to I+2.

	Sample size (LHU cases)	Model 1		Model 2		Model 3		Specification test	
		Odds Ratio (95% CI)	R^2	Odds Ratio (95% CI)	R^2	Odds Ratio (95% CI)	R^2	Wald test	p-value
LHU 1	600 086 (69 725)	0.872 (0.807 – 0.941)	0.078	0.875 (0.810 – 0.946)	0.079	1.017 (0.940 – 1.101)	0.079	2.15	0.142
LHU 2	594 776 (62 738)	0.899 (0.846 – 0.956)	0.074	0.902 (0.846 – 0.961)	0.075	0.991 (0.952 – 1.032)	0.075	5.03	0.025
LHU 3	603 417 (94 839)	0.949 (0.859 – 1.049)	0.083	0.949 (0.856 – 1.052)	0.083	0.911 (0.837 – 0.991)	0.083	1.06	0.304
LHU 4	589 376 (64 711)	1.042 (0.976 – 1.111)	0.079	1.046 (0.980 – 1.117)	0.079	1.240 (1.149 – 1.338)	0.079	10.74	0.001
LHU 5	614 334 (83 973)	0.844 (0.779 – 0.914)	0.079	0.846 (0.779 – 0.919)	0.080	0.860 (0.790 – 0.936)	0.080	3.73	0.05
LHU 6	667 178 (136 817)	0.976 (0.923 – 1.057)	0.079	0.980 (0.905 – 1.061)	0.080	1.076 (0.992 – 1.166)	0.080	0.94	0.331
LHU 7	527 353 (28 246)	0.947 (0.832 – 1.079)	0.087	0.946 (0.826 – 1.083)	0.088	0.937 (0.866 – 1.013)	0.088	0.05	0.820

4.3.3.1. Analysis of the evolution of risk of readmission before and after integration

We performed a logistic regression to analyse DiD in the evolution of risk of readmission in the period pre-integration (I-4 to I-1) and post-integration (I to I+2) in LHU compared with the control group (Figure 6).

An overall look at Figure 6 shows that there was no clear pattern regarding the evolution of risk of readmission. LHU 1 in the pre-integration period presented an increased risk of readmission; in the year I+1 and I+2, the risk of readmission decreased (OR 0.892 and 0.779), presenting statistical significance in year I+2. For LHU 2, the risk of readmission decreased between year I-4 and I-2, then increased until year of integration. In the period after integration, the risk of readmission in LHU 2 was significantly lower when compared to the control group (OR 0.863 and 0.875). For LHU 3, the risk of readmission decreased until year I-2, and then increased in year I-1. Since vertical integration, the risk of readmission decreased in this LHU. In LHU 4 and LHU 6, the risk of readmission did not present a clear pattern in the period prior to vertical integration. Nevertheless, since integration the risk of readmission had been decreasing. We observed a decreased risk of readmission for LHU 5, being statistically significant since year I-1. On the other hand, LHU 7 presented in the same time frame increased risk of readmission, even though without statistical significance. The risk of readmission presented a decrease tendency, but not significantly.
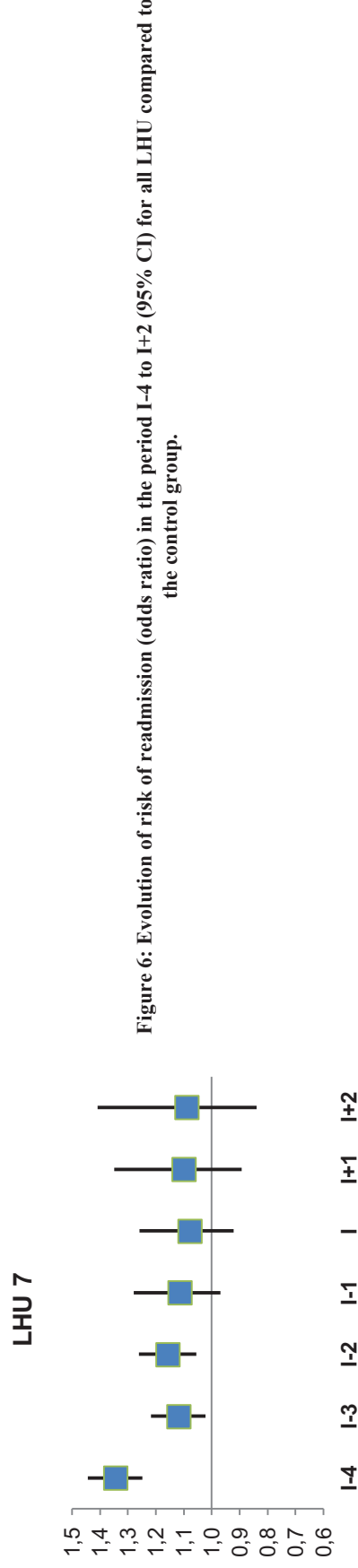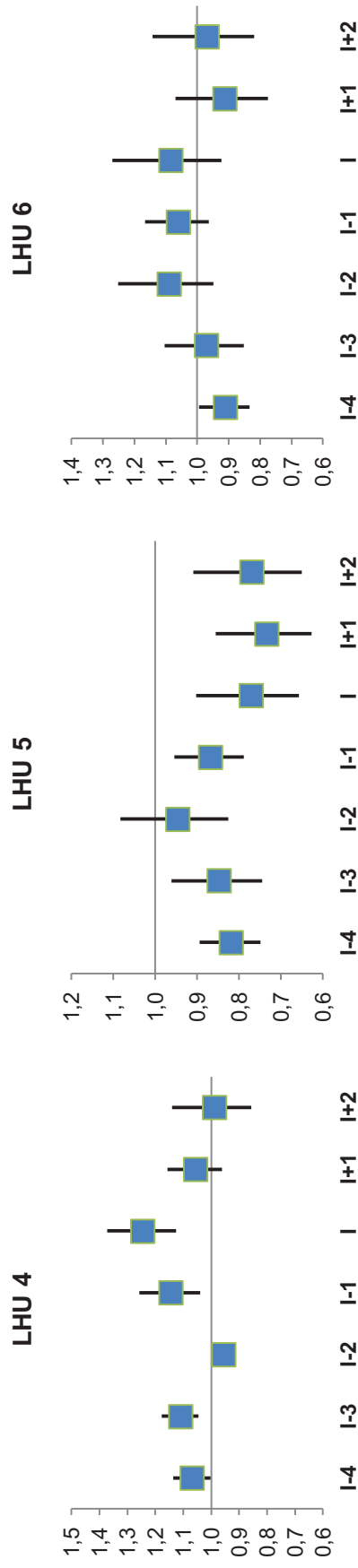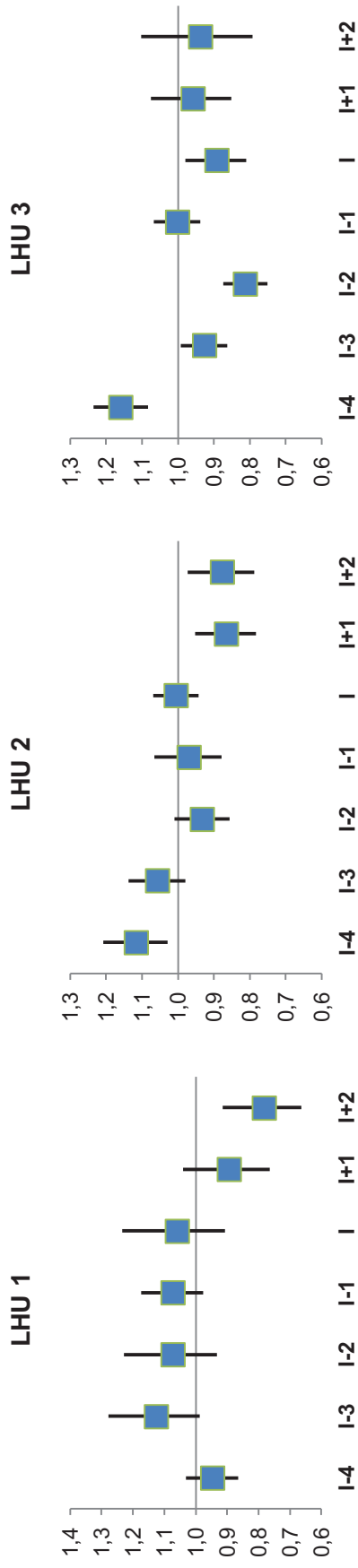
Figure 6: Evolution of risk of readmission (odds ratio) in the period I-4 to I+2 (95% CI) for all LHU compared to the control group.

4.3.3.2. Sensitivity analysis

Table 8 shows the evolution of δ_k of DiD model 4. We conducted a new DiD analysis considering an alternate control group composition, and considered stable all previous results when there was less than 5% difference between odds ratios for the same period.

We observed that previous results were quite stable in most cases, despite the changes in the control group. LHU 2 performed similarly in all years. LHU 7 presented a higher risk of readmission in the new analysis than with the initial control group in years I-4 and I-3, as well as in the post-integration years (I+1 and I+2). This was the only LHU that portrayed this trend, since all other units performed similarly to the initial analysis or improved risk of readmission. LHU 1, LHU 4, LHU 5, and LHU 6 performed better (reduction of the risk of readmission) in some years. LHU 2 was the only unit where all previous results were considered stable.

Table 8: Comparison of the results of difference-in-differences for risk of readmission, obtained considering a different control group, for the period I-4 to I+2.

	I - 4	I - 3	I - 2	I - 1	I	I + 1	I + 2
LHU 1	0.5%	-3.7%	-4.2%	**-6.6%**	-1.5%	0.8%	-4.7%
LHU 2	2.0%	2.6%	-1.5%	-2.0%	-4.8%	0.1%	2.6%
LHU 3	-3.3%	3.7%	**6.3%**	0.3%	-0.2%	0.7%	3.3%
LHU 4	-4.3%	-4.9%	**-7.7%**	-1.7%	0.2%	**-5.1%**	**-5.3%**
LHU 5	0.6%	-3.8%	-4.0%	**-6.6%**	-1.7%	1.1%	-4.8%
LHU 6	0.5%	-3.6%	-4.0%	**-6.6%**	-1.6%	0.9%	**-5.0%**
LHU 7	**6.9%**	**9.4%**	3.6%	3.4%	4.0%	**6.7%**	**6.3%**

4.4. SUMMARY OF MAIN FINDINGS

The main aim of this study was to assess the impact of vertical integration on the readmission of individuals with chronic conditions, and findings suggested that:

- Pneumonia was one of the most frequent diagnoses in LHU and control group (4.4% and 4.7%), and chronic obstructive pulmonary disease and bronchiectasis presented one of the highest readmission rates (LHU: 12.8% and control group: 13.2%);

- LHU and control group presented similar distribution of individuals with chronic conditions;

- LHU average readmission rate from 2002 to 2014 was 4.8%, and for the control group readmission rate was 5.3%;

- The evolution of readmission rates throughout the years stress an increasing gap between LHU and control group since 2007, with the control group presenting higher readmission rates than LHU;

- For individuals with chronic conditions, readmission rates were always higher than national average readmission rate and, for most years and despite the number of chronic conditions, the control group presented higher readmission rates;

- In LHU, the likelihood of readmission was lower for female individuals, increased with increasing age and comorbidities, and reduced with increasing number of chronic conditions;

- Only four LHU decreased crude readmission rates after vertical integration for individuals with one to three chronic conditions (LHU 1, LHU 5, LHU 6 and LHU7). For individuals with more than three chronic conditions, only LHU 3 and LHU 5 were able to decrease their readmission rates;

- Vertical integration promoted a decreasing effect on the risk-standardized readmission ratio for four LHU, but only significantly in LHU 1;

- Vertical integration decreased the risk of readmission in four LHU, but significantly only on LHU 3 and LHU 5;

- The sensitivity analysis showed that our results were robust in most cases to changes in the control group.

CHAPTER 5

DISCUSSION

5.1. DISCUSSION OF MAIN FINDINGS

The main aim of this study was to assess the impact of LHU on the readmission of individuals with chronic conditions. Our findings suggest that LHU present lower readmission rates for individuals with chronic conditions when compared to control hospitals. However, not all LHU were successful in decreasing risk of readmission for individuals with chronic conditions after vertical integration, as there was no clear decreasing pattern for all LHU.

This main finding is consistent with international studies that found similar results over health outcomes, namely readmissions.[9,10,35,57,89,111,112] Comparisons with national studies are difficult because there is a lack of evaluation regarding readmissions[44], specifically those considering individuals with chronic conditions; readmission measure is restricted to an one-year analysis[113]; or the conceptual framework regarding readmission measure is different[88,114]. Also, there is no public reporting over readmission rates, despite the existing evidence that public reporting have a decreasing effect over readmissions[61]. Despite these restrains, a preliminary study regarding LHU effects[44] found that LHU performed no differently compared to non-LHU hospitals in the person-centeredness criteria, and performed worse in terms of individuals security. Hence, one may link these results to an expected effect over readmissions of individuals with chronic conditions.

Our results suggest that four LHU performed better than expected, decreasing the risk of readmission, but three (LHU 1, LHU 4, and LHU 6) performed worse than expected, considering each LHU's service mix and case mix. This variability of the risk of readmission is a sign that despite the existence of barriers to develop an effective integrated care and to promote a person-centred continuum of care, there is potential for improvement.[115] Since our DiD analyses adjusted for individual risk of readmission, these mixed results expose other types of barriers to integrated care and readmission reduction.

Some of the barriers to better integrated care, and more effective readmission reduction, are configured by variations in organizational structures and processes, governance models, and cultural changes that are brought to the table by vertical integration.[27,116] The intensity of these barriers varies across integrated healthcare providers and has different effects on the readmission of individuals with chronic conditions (e.g., Chen and co-authors[117] found no association between readmissions with level and intensity of system integration). But these mixed results could also be partially understood with the insights of a study over LHU, that stressed the lack of perception of clinical integration among physicians and nurses.[118] This lack of perception emerges as increased difficulties to effectively address healthcare needs of individuals with chronic conditions, and thus reducing hospital unplanned readmissions. Despite the specific context and setting of each LHU, and their influence on readmissions, these challenges are common to all LHU.[85] Moreover, this is not a particular situation of the Portuguese LHU, but actually a barrier to all integrated care approaches when developing a continuum of care.[13]

Integrated care barriers are currently under debate[119–121], thus new policies should be developed to promote better health outcomes, namely decreasing readmissions. One possible path to achieve those results could be through the extension of palliative care providers to be vertically integrated with primary care and hospital care. Another barrier that has a direct impact over readmissions is to assume hospitals as the central point for reducing readmissions, despite the multiple factors along the continuum of care that configure the risk of readmission.[122] Therefore, efforts should be made to redress the care system in a holistic way, involving the communities, but still consider the specificity of each level of care, in order to address the root of causes of the readmissions for individuals with chronic conditions.[69] Also, integrated care faces other challenges that could be addressed by: adequate integrated-care-promoting funding schemes, since incentives are not aligned with value[1]; better clinical integration; and a service delivery more aligned with individuals and carers' needs[121].

Our findings suggest that LHU performed no differently than control hospitals for individuals without chronic conditions, decreasing readmission rates in all LHU after integration. However, for increased number of chronic conditions we observed that readmission rates increased in both groups, with higher rates for the control group. Most LHU decreased readmission rates for individuals with one to three chronic conditions, but for those with three and more chronic conditions, the decrease of readmission rates

was not consistent across LHU. These findings suggest that LHU present a reduced risk of readmission when compared to hospitals from the control group. These results may also suggest that LHU provide a better continuum of care for individuals with low chronicity, being aligned with Gruneir and colleagues'[59] study that stresses that the effect of multimorbidity and 30-day readmissions was less pronounced in individuals with greater continuity of care. However, for individuals with more than three chronic conditions and with comorbidities, our data suggests that integrated care is not producing its expected results on decreasing readmissions.

These results somewhat contrast with the multivariate Cox regression results, when we adjust for gender, age, comorbidities and number of chronic conditions. Data suggests increased risk of readmission for male individuals and with increasing age, despite other study found no significant association for gender and age with likelihood of readmission[123]. In other studies, risk of readmission was mostly associated with age, comorbidities and specific types of chronic conditions.[124–128] Findings suggest decreased risk of readmission at LHU with increasing number of chronic conditions. At control group, individuals with two or three chronic conditions presented increased risk of readmission compared to individuals with more than three chronic conditions. Moreover, when adjusting for socio-demographic variables, results suggest that increasing number of chronic conditions are associated with longer time on the 30-day time frame to be readmitted.

These results might seem counterintuitive at first, and conflict with the univariate Cox model, but the fact that we considered various covariates influences multivariate Cox regression estimates. Also, these findings are supported by Graham and colleagues' study[64] that found factors related to chronic conditions burden and social determinants to be associated with readmission, but more substantially in the late period time frame (8-30 days after discharge). So, the results may be related to different experiences of transition of care, which have an association with risk of readmission.[36,63,76] However, this association is done with caution, since there is evidence that transitional care interventions have limited results on 30-day readmission rates[29,77,129], and only high-intensity multi-interventions seem to result in decreased readmission rates for highest-risk individuals[16].

These results highlight several frailties in the continuum of care for individuals with chronic conditions, since unplanned readmissions are not decreasing consistently.

Much work has to be done at a clinical level to develop a more integrated approach, but also at the community-level.

Increased number of chronic conditions are more associated with economic difficulties[130] or low levels of health literacy, thus producing a denser and more complex problem to address. Since readmission for these individuals is more frequent than desired, and care for individuals with chronic conditions is still much focused on an acute care model, different and multiple approaches have to be developed to minimize this problem and to promote a paradigmatic shift. Burke and colleagues[3] found evidence that monitoring and managing symptoms after discharge, enrolling help from individuals' communities, and promoting conditions for self-management through health literacy are associated with decreased risk of readmission, but so is a more effective use of information and communications technology across healthcare providers[78].

Additionally, what individuals and carers perceive as the reasons for – and preventability of – readmissions[62], have indeed an effect on avoiding readmissions[76] and on configuring healthcare professionals' practices.

5.2. LIMITATIONS OF THE STUDY

This study presents a set of limitations that deserve some attention. Our research relies on administrative data and used a retrospective study design, therefore is limited in its ability to prove causation. Another limitation is due to the model we selected to identify readmissions, as well as to predict individual risk of readmission for each index admission. One might assume stated readmission rates as conservative in the sense that, and as referred by another study[131], after a person being discharged alive, one might have died outside the hospital due to the care received. Thus, readmission was prevented and was not considered in this study. This situation is more feasible to happen for individuals with more complex conditions.

There are many models, with varying complexity, to predict readmissions[132], but we chose to use solely the CMS methodology[95,96], that could be considered as analytical bias. The selected chronic condition indicator sets another limitation. The identification of chronic conditions would be different if other aggregator was used (e.g., Tonelli and colleagues[133]). However, we chose AHRQ because its development is well documented, it assesses each ICD-9-CM code to check if the diagnosis is clinically considered to be chronic or not, and offers the possibility to analyse chronicity through body systems.

Another limitation stands out because this is an observational study rather than a controlled trial. For that reason, we might have incurred in some selection bias on choosing control groups (for the main analyses, and for the sensibility analysis) to develop the DiD analyses. Also, the DiD analysis using a logistic regression is slightly biased as previously assumed, but since bias is residual it represents no major prejudice to our study aims. We also point another possible bias, this time related to selection of LHU index admissions. We did not account for the area of residence of individuals treated at these units. It would be very difficult to do so because of the evolution of hospitals distribution across mainland Portugal throughout the years, and the intense hospital horizontal integration phenomena that occurred within that period.

Despite these limitations, and because we did not limit the population under study to a particular age group or to a set of specific conditions like most studies, it can add new information to debate. In addition, this study brings to the fore new information regarding an under-evaluated policy measure (the creation of LHU), and provides more information on the evolution of readmission rates, prevalence of chronicity and comorbidities and their association with readmission.

5.3. FURTHER RESEARCH AND RECOMMENDATIONS

Our main goal was to study the impact of LHU on the readmission of individuals with chronic conditions. Our findings suggest mixed results, so further research is required to develop a deeper understanding of the impact of LHU on individuals' health outcomes and therefore adjust integrated care policy to more effective paths.

The understanding of the effects of social and organizational mechanisms, and their interaction over readmission, is already complex. However, it seems vital to a better understanding of the phenomena to measure how socio-economic factors increase the risk of readmission, specially on those with most complex care needs. Or even to establish casual pathways between socio-economic factors with readmission. To measure these variables and incorporate them into risk-assessment models is complex, but most likely necessary.

There is also a research gap regarding how LHU are addressing more complex individuals' healthcare needs, and how readmissions are being avoided. Our mixed findings over integrated care effects on decreasing risk of readmission for individuals with chronic conditions suggest the existence of different integrated care approaches, and

most likely different levels of integration intensity. Therefore, it seems crucial to understand how some LHU developed positive results in decreasing readmissions over the years, while other did not.

Crossing our findings with what has been the Portuguese integrated care policy framework, we would like to suggest some recommendations. First, it is imperative the development of an integrated care policy, with specialized working teams with the ability and competence to address the organizational challenges that integrated care practices demand, and also address the training needs of LHU professionals. The services of these teams could also be made available for any public hospital who wished to develop integrated care practices, despite not being formally constituted as LHU. The effectiveness and effects of integrated care policy and specialized working teams for a better integrated care has to be measured. The first LHU was created in 1999, and from 2007, a new expansion movement occurred. However, there is still a lack of evidence of this network's effects on delivering better health outcomes (namely on decreasing readmission). A consistent evaluation throughout time facilitates a deeper knowledge of integrated care impacts and stresses the possibility to readapt this policy measure to current healthcare needs, namely addressing the complex needs of people with chronic conditions and multi-comorbidities, and promote an organizational cultural change among healthcare providers of different levels.

Second, person-centeredness is at the core of integrated care. However, individuals' voices (and carers' voices) are quite silent on the construction of a more integrated care approach, with deeper connections on a community-level. So, a national strategy to address chronic conditions should be configured by the ones who will benefit from it the most. This strategy should be intrinsically linked to the recent national education program for health, literacy and self-care[134], empowering individuals with healthcare needs and carers to a better control over their health, hence decreasing acute admissions and readmissions.

Third, addressing individuals with chronic conditions needs is a complex task, because it involves different levels of care, each with its own specificities. Therefore, in order to overcome a hospital-centric care model for these individuals, and thus promoting better and more effective integrated care, payment schemes should considerer adjusted-readmission criteria as a financial incentive to organizations' budgets.

And fourth, health regions should have a more proactive role engaging healthcare organizational structures and populations in the promotion of better health outcomes.[45]

On the one hand, health regions should develop a better understanding of the evolution of populations' health. Cumulatively, health regions should act as dialogue engaging partners for a more integrated care, despite formal constitution of healthcare providers as LHU. Primary and secondary healthcare should develop regional specific disease management programmes or a wider chronic condition care model, involving other levels of healthcare, namely palliative care. A more integrated approach with palliative care can act as key anchor on decreasing readmissions[80], specifically on those with multi-morbidities.

CHAPTER 6

FINAL REMARKS

With this study, our main aim was to understand the impact of vertical integration on the readmission of individuals with chronic conditions. In order to address our aim, we undertook an outcome research, with a longitudinal and retrospective observational design. We compared 30-day readmissions before and after the creation of seven LHU. We considered an eight-year time frame for each studied LHU, five years before integration and three years after, and used difference-in-differences to address our main aim. In order to understand the associations of time to readmission with individuals' risk factors we developed a Cox regression model for LHU and control group.

Cox regression results suggest that for LHU and control group hospitals female individuals are less at risk of readmission, the risk increases with increasing age and number of comorbidities. At LHU, we observed a decreased risk of readmission with increasing number of chronic conditions, suggesting LHU could manage more effectively readmissions. Difference-in-differences results suggest that vertical integration promoted a decreased of risk-standardized readmission ratio in four LHU. Also, when analysed the individual risk of readmission we observed that it was reduced for four LHU, but only significantly for two (LHU 3 and LHU 5). When we performed a sensitivity analysis, annual evolution of odds ratio of risk of readmission was stable for most years.

Integrated care was supposed to address more effectively individuals with chronic conditions and complex healthcare needs, reducing the effects of fragmentation and differentiation across different levels of providers, with a decreasing effect over readmissions. Addressing this problem is a concern to healthcare systems because of ageing populations, increasing prevalence of multiple chronic conditions and burden of disease, hence pressuring healthcare systems sustainability. Thus, reducing the volume of unplanned readmissions is a frequent strategy to promote a more sustainable system, and with better quality for its users.

However, our findings suggest mixed results, with some LHU decreasing their risk of readmission for individuals with chronic conditions, but others did not. This is a sign that even for integrated care, addressing solutions to such a challenge as readmissions is complicated, mainly due to the many factors that contribute to their understanding and decreasing (e.g., inpatient care quality, after discharge care, comorbidities, and social

determinants). Still, reducing hospital readmissions is a priority for health stakeholders. Therefore, much has to be done to develop a more integrated approach, but also at the community-level.

However, the success of Portuguese vertical integration experiences cannot be assessed solely by its effects on the readmissions of individuals with chronic conditions. Instead, a wider set of indicators measuring different dimensions should be considered, as well as an analysis to the efforts developed to mitigate evidence-based known barriers to vertical integration of care. So, in order to promote a better healthcare to individuals with chronic conditions, namely protecting them from readmission, healthcare organizations, despite being formally constituted as LHU, should: develop integrated care pathways for the most prevalent chronic conditions on their catchment area; revise discharge processes; continuously evaluate health outcomes; and share best practices of integration involving community and other levels of care (namely palliative care).

These challenges upon LHU, but also to all healthcare organizations, require a new culture of sharing and openness from healthcare providers. Within this paradigmatic shift, healthcare providers could better address healthcare fragmentation and develop healthcare approaches more person-centred, with its basis on health education and promotion.

In a time where citizens are given unrestricted movement across all hospitals within Portuguese NHS context, empowering citizens' decision-making over their health and well-being, this research adds a space-time of discussion over the design of vertically integrated care approaches and their impacts on health outcomes and system sustainability. Consequently, with this study we also expected to bridge the gap of little evidence regarding both the Portuguese experiences of vertical integration of healthcare and readmission frequency of individuals with chronic conditions, inspiring different level providers to move towards a more integrated healthcare approach.

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APPENDIXES

Appendix 1

Risk-standardized readmission ratio

We estimated the hospital-specific SRR using generalized linear mixed models at the specialty cohort level, modelling data at the individual and hospital levels to account for outcome variance within and between hospitals. For a given specialty cohort, we fitted a hierarchical logistic regression model to account for the natural clustering of observations within hospitals.

Let Y_{it} denote the outcome (1: individual i is readmitted within 30 days) for an individual in one of five mutually exclusive cohort $C \subseteq \{1, \cdots, 5\}$ at hospital j. Let $Z_{ij} = \{Z_1, Z_2, \cdots, Z_k\}$ denote a set of k risk factors. Let M denote the total number of hospital and m_j the number of index individual stays in hospital j. We used the linear relationship between outcome and covariates through a logit function with dispersion

$$logit[Prob(Y_i = 1)] = \mu + \omega_j + \beta * Z_{ij} + \epsilon_{ij}, \text{ with } \omega_j \sim N(0, \tau^2).$$

In the model equation, μ is the adjusted average outcome over all hospitals; ω_j denotes for the hospital-specific intercept, also called the empirical Bayes estimator and; τ^2 is the between hospital variance component. For each year and each specialty cohort a model was ran, in a total of 65 models. Thus, individual risk of occurring a readmission for individual i in hospital j at year t is computed by

$$RR_{ijt} = logit^{-1}(\mu + \beta * Z_{ij}).$$

With the result of each generalized linear mixed model, we computed the predicted and expected number of readmissions at each hospital. The predicted number of readmission is computed as the sum of the predicted probability of readmission for each individual, including the hospital-specific intercept. The expected number of readmission is computed in a similar way, but ignoring the hospital-specific intercept.

Using similar notation to the previous model, for the predicted number of admissions $Pred_{C_j}$ for index admissions in cohort $C \in \{1, \cdots, 5\}$ at hospital j we use $Pred_{C_j} = \sum logit^{-1}(\mu + \omega_j + \beta * Z_{ij})$ where the sum is over all index admissions in cohort C at hospital j. For the expected number of index admissions Exp_{C_j} we use $Exp_{C_j} = \sum logit^{-1}(\mu + \beta * Z_{ij})$. Thus, the risk-standardized readmission ratio in cohort C at hospital j $\left(SRR_{C_j}\right)$ is computed as $Pred_{C_j}/Exp_{C_j}$. The risk-standardized readmission ratio at the hospital level is a combination of all specialties cohort SRR_{C_j}

pooled for each hospital using a volume-weighted logarithmic mean to create a hospital-wide SRR composite:

$$SRR_j = exp\left\{\left[\sum m_{C_j} \, ln\left(SRR_{C_j}\right)\right] \middle/ \sum m_{C_j}\right\}.$$

The use of a geometric mean is a more appropriate indicator to summarize benchmark results.[135] Thus, given a hospital case mix and service mix, we are able to compare with an average hospital's performance with the same case mix and service mix. A lower ratio (<1) is a sign of lower-than-expected readmission rates or, in other words, better quality; on the other hand, a ratio higher than 1 denotes a higher-than-expected readmission rate.