Low Bed Occupancy: A Life-Saving Strategy or a Costly Illusion? Evidence from Two Natural Experiments

March 2025

Netanel A. Horowitz[1,2], Lev Drucker, Shlomo Pashkos[1], Michael Halberthal[1,2]

[1]Hospital Management, Rambam Health Care Campus, Haifa, Israel

[2]Rappaport faculty of medicine, Technion, Haifa, Israel.

Abstract

Lower hospital bed occupancy is perceived to improve patient survival and is a key consideration in resource allocation. We use administrative data from large Israeli hospital during two distinct events of large unexpected reductions in bed occupancy to assess the causal impact of occupancy on patients' mortality. A difference-in-differences methodology, with controls for key patient's metrics analyzed in existing literature - such as Norton and Charlston indexes and prior hospitalization history is applied consistently to periods including the COVID-19 and Iron Swords war events. We do not find robust, significant effect of occupancy on a survival rates, albeit the relevant coefficients hint to some benefit to patients. We find stronger evidence for the benefit of low occupancy among ICU admitted patients or those transferred to the unit after admission. Our results contradict some findings in existing literature that report correlation between high bed occupancy and increased mortality rates. Considering the high economic costs involved in reducing bed occupancy rates, there is a reason to focus on improving capacity in internal medicine departments for specific groups of patients, particularly those with complex medical conditions.

The views expressed are those of the authors alone.

This study was supported by a research grant from the Israel National Institute for Health Policy Research

Introduction

High hospital bed occupancy rates are frequently associated with increased inpatient mortality. A study analyzing admissions to Danish hospitals' departments of medicine between 1995-2012 found that high bed occupancy was linked to a significant (9%) increase in in-hospital mortality and 30-day mortality compared to low bed occupancy(1). Similarly, a retrospective longitudinal study conducted at general hospitals in Switzerland showed that for each additional day of exposure to high-capacity utilization, there was a 2% increase in the odds of 14-day in-hospital mortality(2). During the COVID-19 pandemic, an association between hospital bed occupancy and increased 30-day in-hospital mortality of patients with COVID-19 was observed, with a 0.7% mortality increase for each 1% increase in bed occupancy(3). Data obtained from the English National Health Service in the pre-COVID-19 era, demonstrated a positive correlation of higher bed occupancy rates with both overall and surgical mortality(4). Likewise, during the COVID-19 pandemic high levels of bed-strain were found to be associated with higher in-hospital mortality rates in England(5). Furthermore, a large retrospective cohort study conducted in Mexico City using three open data sources, showed that higher hospital bed saturation elevated the hazard of dying without being intubated and worsened the outcomes in mechanically ventilated patients(6). These findings suggest that hospital bed occupancy is an independent risk factor for patient mortality and that strategies to manage capacity utilization and maintain adequate resources are crucial for improving patient outcomes.

The pertinent question is whether medical literature can provide data demonstrating that low hospital bed occupancy or interventions aimed at reducing occupancy, lead to a decrease in mortality rates among hospitalized patients. The literature addressing this specific question is more limited. The study by Boden et al. demonstrated that interventions to reduce medical bed occupancy in a UK District General Hospital were associated with a reduction in hospital mortality(7). The mean medical bed occupancy significantly decreased from 93.7% to 90.2%, and this reduction was associated with a mean decrease in all mortality markers, ranging 4.5-4.8%. That study used segmented regression analysis of interrupted time-series to estimate changes in mortality measures, which showed significant trend changes in the Summary Hospital-level Mortality Indicator (SHMI) and crude mortality after the intervention. This evidence suggests that lowering hospital bed occupancy can be associated with lower mortality rates.

The COVID-19 pandemic provided a kind of "natural experiment" regarding the issue of reducing hospital occupancy. Many centers reported a decrease in the occupancy of beds not designated for COVID-19 patients, especially during the initial waves of the crisis. This reduction could be attributed, at least in part, to patient avoidance. The study by Kazakova et al. documented a 50% decrease in hospitalizations in April 2020, with the greatest declines occurring in same-day surgery(8). Birkmeyer et al. also found that non-COVID-19 admissions fell dramatically from February to April 2020, with declines generally similar across patient demographic subgroups(9). The cross-sectional Rotterdam study revealed that 20.2% of participants avoided healthcare, with 36.3% reporting symptoms that potentially warranted urgent evaluation(10). These findings suggest that patient avoidance contributed to lower hospital bed occupancy during the pandemic.

A priori, an analysis of the relationship between decreased bed occupancy and hospital performance and efficiency may reveal a complex interplay of factors. Reduced occupancy rates may lead to decreased hospital revenues and financial strain, as seen in the study by Rhodes et al., reporting that operating margins declined by an average of 5.3 percentage points between 2019 and 2020(11). This financial impact can affect the ability of hospitals to maintain staffing levels and other operational necessities. On the other hand, lower occupancy rates could also allow hospitals to allocate resources more effectively. For instance, lower occupancy rates might lead to improved waiting times for outpatient appointments and elective surgeries, as demonstrated in the study by Alharbi et al., where waiting times for outpatient appointments were found to decrease during the early phase of the COVID-19 pandemic(12). However, this should be balanced against the potential for deferred care and the progression of untreated conditions, as highlighted in the analysis by French et al., reporting that suspension of multiple preventive and elective procedures led to the progression of serious conditions in some individuals(13).

Overall, the implications of lower hospital occupancy for hospitals efficiency and performance are multifaceted, with both potential benefits and drawbacks that need to be carefully managed. No evidence has been found in the medical literature that directly addresses all aspects of this complex issue. Intuitively, one might expect that the reduced bed occupancy for non-COVID-19 patients would result in lower mortality rates and fewer readmissions compared to pre-pandemic times, given the hospital's ability to reallocate

resources. However, the data presents a surprising counter-narrative. Several studies compared mortality rates among non-COVID-19 patients during the pandemic with those from previous years or periods without a pandemic. The systematic review and meta-analysis by Lau et al. examining the effects of the COVID-19 pandemic on patients with a non-COVID illness and on healthcare systems relative to the non-pandemic era(21), revealed an increased mortality rate of 16% during the pandemic compared to 11% mortality in the pre-pandemic period, with a relative risk of 1.38. In the nationwide population-based cohort study from Denmark, assessing the incidence of hospital admissions and associated mortality rates for non-COVID medical conditions during the COVID-19 pandemic compared to the pre-pandemic period(17), the overall 30-day mortality rates were found to be higher during the first and second national lockdowns relative to pre-pandemic levels. Likewise, McLarty et al. reported an increase in ICU mortality among non-COVID-19 admissions during the pandemic, with elevated mortality observed in middle-income countries, while a reduction in these values was documented in high-income countries(18). As to the data related to major specific diagnostic categories, the study conducted at the King's College Hospital in London (UK) and focusing on cardiovascular (CV) conditions, reported a significant increase in in-hospital mortality among non-COVID-19 patients admitted with CV diseases during the pandemic compared to periods outside the pandemic(22). Overall, these studies provide evidence that mortality rates for non-COVID-19 patients during the pandemic were higher relative to those observed in pre-pandemic periods. Overall, the impact of lower hospital occupancy on non-COVID-19 patient mortality and readmissions during the pandemic appears to be complex and condition-specific, with some studies reporting increased mortality or readmission for certain patient groups, while others report decreased readmission rates. No evidence has been found that directly links lower occupancy rates to decreased mortality or readmission risk for non-COVID-19 patients during the pandemic.

Several factors could influence the relatively high mortality rates for non-COVID-19 patients during the pandemic. The study by Birkmeyer et al. indicated that non-COVID-19 admissions fell dramatically across all primary admission diagnoses, suggesting that patients with acute medical illnesses may have delayed seeking hospital care, which could potentially lead to adverse outcomes(9). Yousufuddin et al. found that while the 30-day readmission rate for heart failure patients decreased during the pandemic, all-cause mortality increased, which might be related to changes in healthcare delivery and patient

behavior during the pandemic(15). The nationwide cohort study from Denmark reported that hospital admissions for non-COVID-19 conditions decreased during national lockdowns, and mortality rates were higher overall and for patients admitted with conditions such as respiratory diseases, cancer, pneumonia, and sepsis(17). This suggests that the pandemic may have affected the management of serious non-COVID-19 medical conditions. Indeed, Kazakova et al. recorded declines in hospital-based care, which could have long-term implications for population health and hospital workforce(8). Interestingly, the multinational registry-based study including data from 15 countries, demonstrated an increase in ICU mortality among non-COVID-19 admissions during the pandemic, particularly in middle-income countries, suggesting that healthcare spending, policy pandemic responses, and ICU strain might play significant roles(18). A retrospective cohort study from Canada found no difference in readmission rates before or during the pandemic for colorectal surgery patients, indicating that enhanced pressure to keep patients out of the hospital did not lead to hasty discharges requiring re-admission(19). These studies collectively suggest that the healthcare system strain, changes in patient behavior, and disruptions in care delivery during the pandemic could have influenced mortality and readmission rates for non-COVID-19 patients.

A significant distinction between Israel and other countries emerges when considering this issue. While many countries grappled with overwhelming COVID-19 caseloads, necessitating a reallocation of hospital resources towards these patients, Israel experienced relatively low rates of severe COVID-19 illness during the initial waves. Consequently, hospitals reported lower bed occupancy, facilitating the provision of higher quality care for non-COVID-19 patients. However, even if mortality rates for this patient group declined, it remains crucial to evaluate the associated costs of reduced bed occupancy and whether these costs are commensurate with the observed improvements in mortality.

No sources in the medical literature have been found to directly address the issue of cost analysis of lowering hospital bed occupancy in relation to mortality rates. However, it is generally understood that hospital bed occupancy has implications for both healthcare costs and patient outcomes. The optimization of bed occupancy involves balancing the need for adequate patient access to beds with the costs associated with maintaining those beds. High occupancy can lead to increased costs due to factors, such as overtime pay for

staff, the need for temporary staff, and the potential for increased length of stay, if patient flow is impeded. Conversely, too low occupancy can result in underutilization of resources. Cost analyses would need to consider these factors along with a potential impact on mortality rates to provide comprehensive understanding of the financial implications of bed occupancy rates.

Finally, the prevailing security crisis in Israel presents a contextual framework within which to assess the generalizability of the findings derived from our analysis of the COVID-19 data. The renewed decline in hospital referrals and bed occupancy rates during fall of 2023, analogous to a "natural experiment," provides a compelling opportunity to re-examine the research question at hand.

The primary objective of this study is to assess the association between decreased bed occupancy in a tertiary academic hospital during the initial phase of the COVID-19 pandemic and mortality rates among non-COVID-19 patients. A causal analysis of mortality rates in treatment and control groups will be performed using difference-in-difference methodology. To enhance the robustness of our findings, an additional dataset from the recent conflict in Israel is analyzed (which led to lower admissions due to security situation). Moreover, an economic evaluation of the resource implications of hospital-initiated interventions aimed at reducing inpatient bed occupancy will be undertaken.

1. Rapid changes in hospital capacity

To evaluate the impact of occupancy rates on clinical outcomes, it is essential to study periods with significant variability in occupancy. This variability allows for an examination of the differences in clinical results for patients relative to the resources invested in them.

In routine times, the average occupancy rate of internal medicine departments at RHCC is relatively high with minimal variability. For example, the average occupancy rate in 2019 was 98.4% with a standard deviation of 4.5%. This situation does not allow for a robust statistical analysis of the impact of occupancy on clinical and economic outcomes.

On March 14, 2020, the first wave of COVID-19 led to strict closedown measures in Israel and lasted until the end of May. With the onset of the COVID-19 pandemic in Israel, a unique phenomenon occurred where the volume of admissions to emergency

departments in Israel dramatically decreased. This phenomenon was also observed at RHCC. From March to May 2019, there were an average of 285 admissions to the emergency department per day, compared to 204 during the same period in 2020, reflecting a 28% decrease in emergency department visits. Consequently, the number of hospital admissions to internal medicine departments, which rely on the emergency department, also significantly decreased from an average of 45 patients per day in 2019 to 36 patients per day during the aforementioned months in 2020, representing a 20% reduction (refer to Figure 2 for admissions in estimation sample).

This rapid change created a natural experiment that enables the examination of the effects of reduced occupancy on the performance of internal medicine departments. Between March 14 and May 31, 2019, the average occupancy rate in the internal medicine departments at Rambam was 99%, whereas during the same period in 2020, the average occupancy rate was 75%.

A central hypothesis is that when occupancy is lower, there is greater allocation of resources per patient, which should be reflected in several ways. Firstly, the staff in the department has more time to dedicate to each patient. This aspect is not measurable as there is no documentation of caregiver-patient contact time. Secondly, the hospital's supporting infrastructure is less utilized, allowing for greater resource allocation per patient in services provided by other units within the hospital. These services include consultations, imaging tests, laboratory tests, and other invasive procedures such as catheterizations and gastroenterological procedures.

To illustrate this phenomenon, we compared the frequency of common imaging tests performed per patient during the first wave of COVID-19 with the frequency of these tests during the same period in 2018 and 2019. The table below shows that the number of imaging tests per patient increased during the pandemic.

Table 1. **Frequency of common imaging studies performed during the first sub-period 2018-2020.**

	CT	X-Ray	Echo	Catheterization
2018 + 2019	0.815	1.931	0.208	0.148
2020	0.917	2.006	0.229	0.197

Additionally, we compared the number of consultations per patient between the periods, which stood at 1.26 in 2019 and 1.34 in 2020, reflecting a 7% increase.

Naturally, the cost per hospitalization during the COVID-19 period was significantly higher compared to the same period in previous years. For illustration, the average direct cost per hospitalization in 2019 was 13,997, while during the COVID-19 period it was 16,221.

The decrease in emergency department visits also resulted in a change in the profile of patients. The concerns regarding contagion or security situation reduced admissions of patients that were less severely ill and could afford to postpone visiting the hospital. This phenomenon can be seen in hospitalized patient’s primary severity scores (Charlson and Norton indices) that were 5.65 and 15.94 during Covid-19 first lockdown and 5.58 and 16.14 during the preceding period. Similar change in admission scores was observed for the second period (refer to Table 2a and Table 2b).

The observation regarding higher severity of medical condition among patients during the treatment period presents a methodological challenge since these patients are naturally expected to have poorer clinical outcomes and higher costs. The methodology section will elaborate on how we addressed this methodological challenge.

A similar phenomenon occurred at the hospital in the last quarter of 2023. On October 7, Israel experienced a brutal attack by Hamas, leading to the outbreak of the "Iron Swords" war. This war also caused a significant decrease in the volume of emergency department visits across hospitals in Israel.

In October, November, and December 2022 (from October 7), there were an average of 437 emergency department visits per day, compared to 387 during the same period in 2023, reflecting an 11% decrease in the later period. Consequently, the number of hospital

admissions to internal medicine departments decreased significantly from 42 patients per day in 2022 to 38 patients per day in 2023, representing a 10% reduction.

This situation creates an additional natural experiment that allows for the re-examination of the effects of reduced occupancy on the performance of internal medicine departments. Between October, November, and December 2022 (from October 7), the average occupancy rate in the internal medicine departments at Rambam was 96%, whereas during the same period in 2023, the average occupancy rate was 81%.

2. Data

3.1 Sources and key variables

Our empirical analysis relies on administrative records of the Rambam (Rambam Health Care Campus). We aggregate data from 2 sources (refer to Appendix A for detail description):

- NMR system, managing the medical administrative information of patients
- Prometheus system, managing medical data records

We use the patient's admission dates to allocate observations to post and pre-periods. For the **first data sample**, the threshold date is '2020-03-14', when strict Covid related lockdown restrictions were implemented in Israel. Regarding the **second data sample**, the treatment start date is '2023-10-07' which represents 'Iron Swards' war.

For each admitted patient we collect key variables describing her relevant medical history. The definitions and descriptive statistics of the variables are discussed below. The variables in the study have been chosen according to the existing literature covering mortality rate.

3.2 Definitions for Charlson Comorbidity Index, Norton Scale and ICU patients

The **Charlson Comorbidity Index** (CCI) is a tool used to quantify the burden of comorbid conditions and predict the risk of patient's mortality. The index assigns weighted scores to 19 medical conditions, with more severe conditions receiving higher scores. The cumulative score provides an estimate of the patient's overall health status, which correlates with increased risk of mortality and complications. The CCI is widely used in clinical practice and research for risk stratification, outcome prediction, and controlling for comorbidity in comparative studies. A higher total score reflects a greater burden of comorbidities and a higher likelihood of adverse outcomes.

The **Norton Scale** is a clinical tool used to assess the risk of pressure ulcers in patients. It evaluates five key parameters: physical condition, nutrition, mental state, activity, and mobility. Each parameter is scored from 1 to 4, with lower scores indicating a higher risk of developing pressure ulcers. The total score helps healthcare providers identify patients at risk, particularly those with limited mobility or compromised health. The Norton Scale is widely

ICU patient - a patient who, during his hospitalization, was admitted to the Intensive Care Unit (ICU) or initially started their hospitalization in the ICU and then was transferred to an internal medicine department before discharge, or started the hospitalization in the internal medicine department, was transferred to the ICU, and subsequently returned to the internal medicine department before discharge.

3.3 Estimation Sample

We impose several restrictions to construct our analysis sample. For the first sample we exclude patients admitted during the 3rd quarter of each year. This information is not needed in the diff-in-diff analysis and has been removed to protect patients' data. In both samples, we retain observations where patients were admitted to internal, cardiology and neurology departments without positive Covid-19 indication.

Finally, we exclude patients that were not referred by HMOs as mortality rate across other referral institutions (such as prisons) can be substantially different. The first period sample includes 21,151 observations and the second period covers 8,212 observations.

3.4 Descriptive statistics

Tables 2a and 2b provide descriptive statistics for our analysis sample. On average, in the first period the mortality rate was 11.8%. Majority of the mortality 8.7% was recorded during the hospitalization period, with the remainder occurred within 30 days period after the discharge.

Table 2a: Variables Used in Study and Descriptive Statistics for the first sub-period 2018-2020

	Control (periods not including post period)			Treatment (post period)		
Variable	N	Mean	St. Dev	N	Mean	St. Dev
Death	18691	11.98%	0.324	2460	11.59%	0.320
Medicines	18691	7.02	5.17	2460	7.11	5.220
Female	18691	45.64%	0.498	2460	44.15%	0.496
Age	18691	66.88	17.80	2460	66.99	17.57
Norton	18635	16.14	4.15	2453	15.94	15.94
Charlson	18691	5.58	3.81	2460	5.65	3.880
Re-hospitalization	18691	23.28%	0.422	2460	23.54%	0.424
ICU	18691	6.91%	0.253	2460	9.31%	0.291
Spring	18691	34.21%	0.474	2460	100%	0

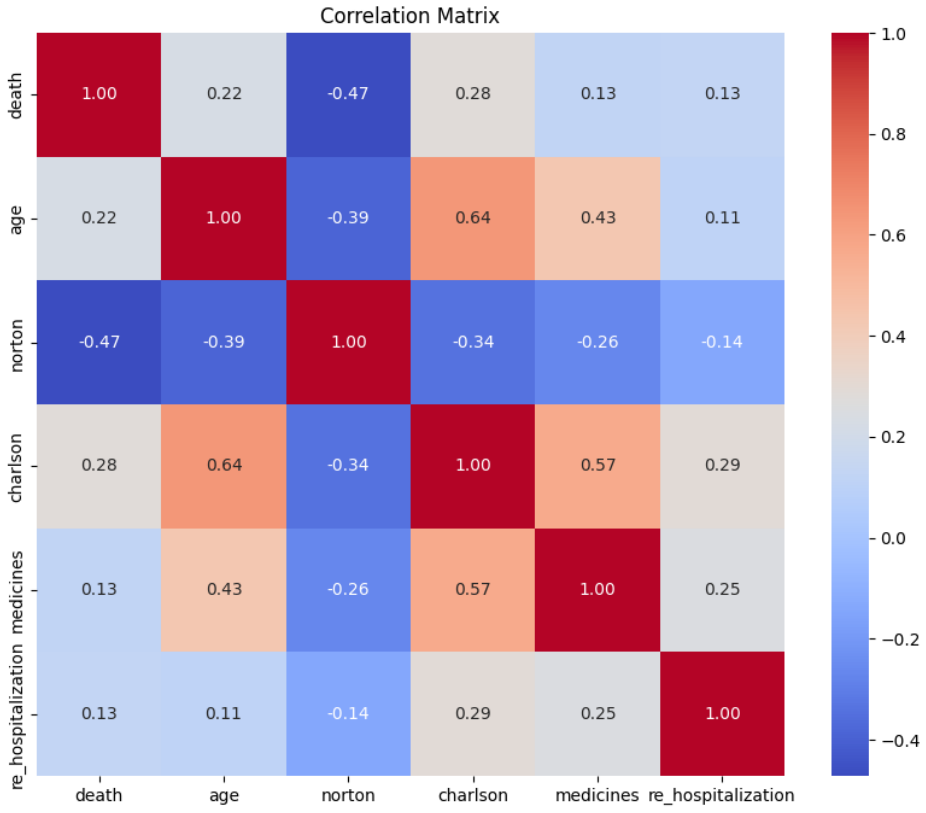
Table 2b: Variables Used in Study and Descriptive Statistics for the second sub-period 2022-2023

	Control (periods not including post)			Treatment (post period)		
Variable	N	Mean	St. Dev	N	Mean	St. Dev
Death	5763	11.02%	0.313	2449	10.07%	0.309
Medicines	5763	7.11	5.18	2449	7.51	5.230
Female	5763	45.22%	0.497	2449	44.51%	0.497
Age	5763	66.51	17.92	2449	67.09	17.80
Norton	5735	16.15	4.25	2438	16.04	4.280
Charlson	5763	5.55	3.89	2449	5.79	3.940
Re-hospitalization	5763	23.95%	0.426	2449	24.66%	0.431
ICU	5763	6.94%	0.254	2449	5.55%	0.229

Average age in the sample was 66.5 years, with the younger 25% percentile of distribution aged close to 56 years, and the 75% percentile slightly above 80 years old. Interestingly, average age of admitted female patients was 68.7 years, more than 3 years older than male patients.

The average Norton scale value was 16.1, ranging between 14 and 18 (for the 25-75% percentile range). Norton scale, which assesses the risk of pressure ulcers, is defined earlier in this chapter. In both samples the Norton scale value displays a strong negative correlation with age and Charlson index. Charlson index (see description above) in the sample averages around 5.6 and ranges at 3-8 values (for the 25-75% range). Both features, Norton and Charlson appear to be correlated with mortality, with Norton correlated negatively and Charlson displaying positive correlation. We will discuss the causal links in depth in the next chapter.

Figure 1: Cross correlation of key variables, first sample period 2017-2020

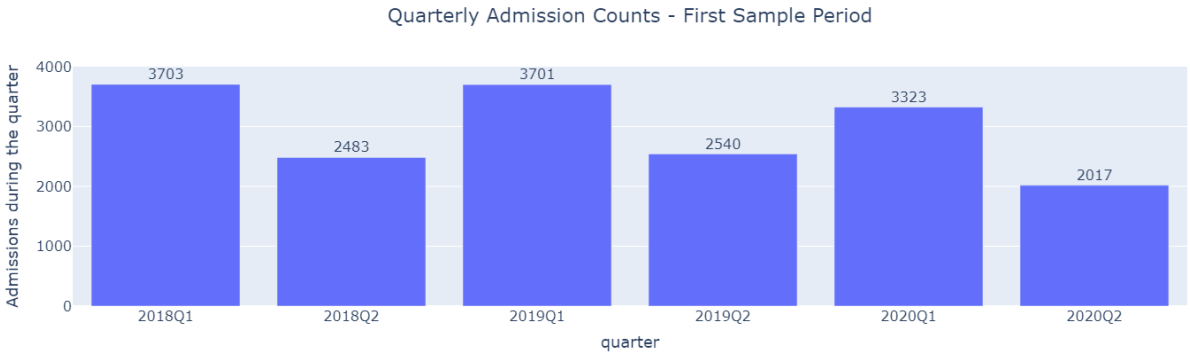


Re-hospitalization, is a binary variable representing prior hospitalization withing 6-month

period. The average value for the sample was 23%.

Average occupancy rate was 98.7%, with rates ranging 93.7-104.1% (for the 25-75% range). Figure 2 shows the admissions peaks during the 1st quarters of the year, with the 2nd quarters recording lower number of admitted patients.

Figure 2: Admissions in first and second quarters, first sample period 2017-2020



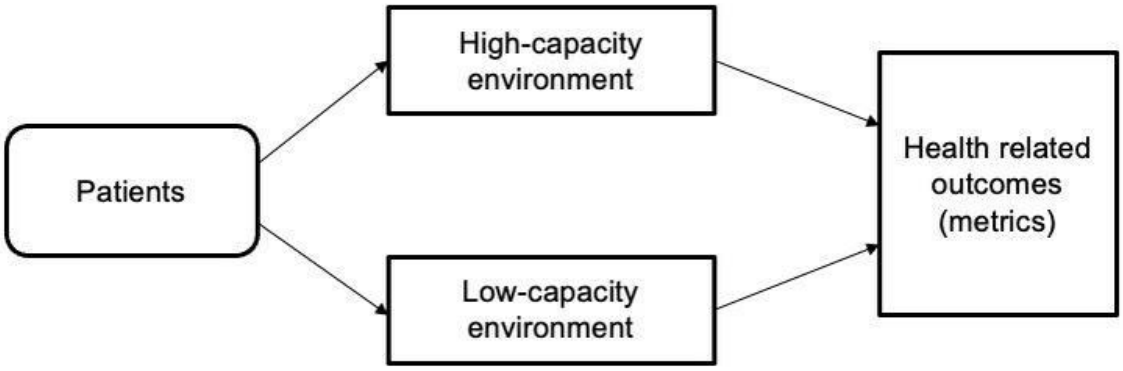
We define post period for the diff-in-diff analysis as starting at '2020-03-13' and ending at '2020-05-31' which is the most recent date of the first sample.

3. Methodology

4.1 Difference-in-difference methodology

We selected a diff-in-diff methodology for causal inference in periods of natural experiment. This method allows to distinguish between a *homogeneous* group of patients (or group of patients with variance that we can control using observable variables) that were exposed to differential treatment (hospital capacity environment).

Figure 3: Comparing mortality for treatment and control groups



We explore the data from two natural experiments that rapidly created high-capacity environment in the hospital. Overall, the specification we estimate is as follows:

(1) $$\theta_{i,t} = \alpha + \beta X_{i,t} + \gamma S_t + \eta S_t * post + \epsilon_{i,t}$$

Where $\theta_{i,t}$ is the survival status of the patient during hospitalization and in a 30 days period thereafter, α is the intercept of mortality odds controlling for all other factors, $X_{i,t}$ is vector of the admission patients characteristics such as Norton and Charlston indexes, use of medications, age and gender. S_t capture seasonality dummies. The last variable is indication of treatment period and provides an indication if the death probability changed during high-capacity environment periods (Covid or Iron Swords).

However, high-capacity environment could be more beneficial for sub group of patients. For example, waiting times and staff and equipment availability can have a

disproportionally larger effect on intensive care unit patients. To allow for this possibility we estimate the differential effect on two groups of patients:

- Patients being admitted via ICU ()
- Other patients in the sample

The specification is as follows:

(2) $$\theta_{i,t} = \alpha + \delta E_i + \beta X_{i,t} + \gamma S_t + \eta S_t * post * E_i + \epsilon_{i,t}$$

Where:

As before, where $\theta_{i,t}$ is the survival status of the patient during hospitalization and in a 6 month period thereafter, α is the intercept of death probability controlling for all other factors,

$X_{i,t}$ are the admission patients characteristics such as Norton and Charlston indexes, use of medications, age and gender. E_i is a binary variable for admission via ICU and the interaction of this variable with the post period can provide indication whether the effect of high-capacity environment is higher for the specific group of patients.

4. Estimation results

5.1 Did the higher capacity reduced death probability for all patients?

In this chapter we will present and discuss estimation results of the specifications described above.

Table 3: Mortality odds for admitted patients during two sample periods, 2017-2020 and 2022-2023

	Low-occupancy period 1	Low-occupancy period 2
Intercept	6.04*** (0.86)	3.68*** (1.37)
Norton[1]	-3.44*** (0.07)	-3.19*** (0.12)
Charlson[1]	1.32*** (0.06)	1.07*** (0.10)
Age[1]	0.056 (0.163)	0.39 (0.26)
Female	-0.22*** (0.05)	-0.14* (0.09)
Re-hospitalization	0.33*** (0.06)	0.31*** (0.09)
Medicines > 3	-0.037*** (0.08)	0.03 (0.14)
ICU	-0.07 (0.12)	-0.40* (0.21)
Spring	-0.10* (0.06)	..
Post	-0.09 (0.09)	-0.11 (0.09)
N	21,088	8,173
Pseudo R^2	0.316	0.291

ce type

White (1980) heteroscedasticity-robust standard errors. Standard errors in parentheses.
Levels of significance: 10%*, 5%**, 1%***.

[1] Transformed using inverse sine (similar to log transformation).

Before discussing the effect of capacity, we want to compare how our findings regarding variables correlated with death probability compare to existing literature:

- Larger values of Charlston index are positively correlated with a probability of mortality during the period of hospitalization of 30 days after discharge. Increase of 10% in Charlston compared to an average value of 5.6 in the first period sample, increases death probability by 3.3 percentage points (applicable to the base rate of 11.9%).
- Norton index helps to predict survival probability. According to our results, patients with Norton index higher by 10% are expected to have 1.2 percentage points higher survival rate.
- Female patients have 16% higher probability of survival compared to men, equivalent to 2 percentage points lower death rate). This estimate is larger than the differences in the base rate observed in the groups during the first period (10.7% men, 11.3% women) and can be partially attributed to the higher average age of hospitalized women in the data.
- Patients with a recorded history of prior hospitalization have 37% higher odds[2] of not surviving the relevant period.
- Age does not seem to be directly correlated with survival probability after controlling for other variables in the specification.

Now, that we established general consistence of the results to the existing literature we can discuss effect of the high-capacity periods on mortality. In both periods, we find negative but statistically insignificant effect for the overall patients. However, it could also indicate that the effect can be significant to sub-group of patients that benefit from higher capacity the most.

5.2 Did the higher capacity reduced death probability for patients admitted via ICU?

As mentioned earlier, it could be that the high-capacity environment is beneficial for sub group of patients. Indeed, mortality rate among those patients is significantly higher 17.3% compared with 10.5% for the non-ICU admitted patients. Therefore, we estimate and report below results for equation 2:

[2] The coefficients reported in tables 3 and 4 are in terms of log odds.

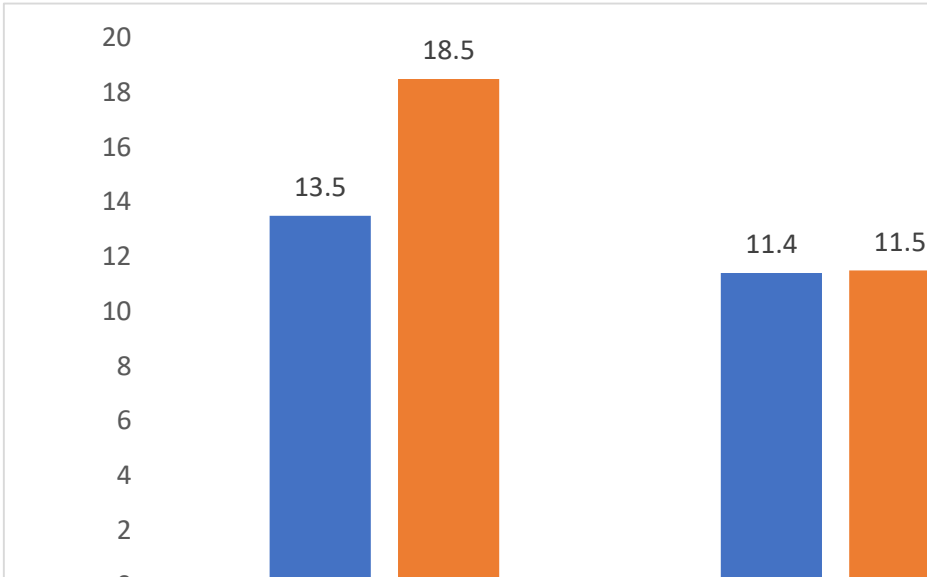
Table 4: Mortality odds for admitted patients during two sample periods, 2017-2020 and 2022-2023, including ICU*Post interaction variable

	high-capacity period 1	high-capacity period 2
Intercept	6.00*** (0.86)	3.65*** (1.37)
Norton (Transformed using inverse sine, similar to log)	-3.45*** (0.07)	-3.19*** (0.12)
Charlson (Transformed using inverse sine, similar to log)	1.32*** (0.06)	1.07*** (0.10)
Age (Transformed using inverse sine, similar to log)	0.06 (0.163)	0.40 (0.26)
Female	-0.22*** (0.05)	-0.14* (0.09)
Re-hospitalization	0.33*** (0.06)	0.31*** (0.09)
Medicines > 3	-0.37*** (0.08)	0.03 (0.14)
ICU	0.02 (0.12)	-0.34 (0.23)
Spring	-0.10* (0.06)	..
Post	-0.09 (0.09)	-0.09 (0.09)
Post * ICU	-0.72** (0.31)	-0.28 (0.46)
N	21,088	8,173
Pseudo R2	0.316	0.291

Notes: Dependent variable is mortality (0 survived, 1 did not survived). Covariance type White (1980) heteroscedasticity-robust standard errors. Standard errors in parentheses. Levels of significance: 10%*, 5%**, 1%***.

According to the results in the first high-capacity period, the added capacity improved ICU patient's survival rate by 6.1%, an impressive result considering mortality rates for the group (17.3% in the first period).

Figure 3: Observed average mortality rates for ICU and other patients, first sample



However, the effect is not significant in the second period. This can be attributed to the shifting pattern of patients admitted via ICU – base mortality rate differential in the second period was significantly lower (12.4% for ICU compared to 10.7% non-ICU). This can attenuate the potential benefit and make our results insignificant.

To summarize, we explore the effect of higher-then-usual hospital capacity on patients' mortality in two separate events that create natural experiments. Overall, we do not find robust significant effect of capacity on a survival rates, albeit the relevant coefficients hint to some benefit to patients. We find more evidence for the benefit of high capacity among ICU admitted patients.

5. Cost analysis

When analyzing hospitalization costs within the healthcare system, a comprehensive, multi-faceted approach is required, encompassing various components that must be examined thoroughly. These costs vary significantly across different medical services and directly impact the hospital's overall budget. A detailed breakdown of the hospitalization cost components includes:

1. **Medical and Nursing Staff**: This category includes the salaries and associated costs of the medical and nursing teams providing care to hospitalized patients, allocated directly to the inpatient department where they are treated .

2. **Laboratory Tests**: Includes the costs of a range of laboratory studies, i.e. blood tests, urine analyses, as well as bacteriological or other biochemical tests.

3. **Imaging and Diagnostic Procedures**: Covers the costs of imaging studies, including ultrasound, X-ray, CT, and MRI, as well as specialized diagnostics such as gastroenterological and pulmonary evaluations essential for diagnosis and treatment .

4. **Specialist Consultations**: This component accounts for expenses related to specialist consultations, examinations, and clinical recommendations provided to patients during hospitalization .

5. **Medications and Consumable Medical Supplies**: Includes the costs of medications administered during the hospital stay and consumable medical supplies required for treatment .

6**. Hospital fixed Costs**: Refers to general operational costs, such as administrative expenses, logistical support, infrastructure, and the maintenance of essential systems and equipment .

To evaluate the impact of bed occupancy on hospitalization costs, it is essential to distinguish between variable costs, which fluctuate with hospital occupancy, and fixed costs, which remain unchanged. This analysis will focus solely on variable costs—such as ward staff salaries, medications, consumables, diagnostic expenses, and consultations—

as these are directly influenced by occupancy levels and the specific medical needs of each patient.

To evaluate the impact of changes in bed occupancy on hospitalization costs, a comparative analysis of data from two distinct time periods is presented: May 2019–2020 and December 2022–2023.

Table 5. **Differential cost (NIS per patient) analysis for first study periods**

(Negative sign represents expenditure)

	Mar-Apr 2020	Mar-April 2019	Difference
Laboratory studies	-1,192	-1,061	12%
Imaging and Diagnostic Procedures	-1,587	-1,342	18%
Consultations	-187	-265	-29%
Medical stuff	-7,829	-6,430	22%
Nursing stuff	-3,717	-3,038	22%
Medications and Consumable Supplies	-1,707	-1,860	-8%
Total	-16,221	-13,997	16%

It can be observed that the total cost per hospitalized patient increased by 16%, from 13,997 ILS to 16,221 ILS, representing an increase of 2,224 ILS. The highest cost increase was in the area of nursing care, which rose by 22%, while the cost of medical hospitalization also increased by an additional 22%. Conversely, the costs of medications and consumable medical supplies (MMS) decreased by 8%, and there was a significant reduction in the cost of medical consultations. This decrease may be explained by the absence of significant workload on the medical and nursing staff, allowing them to manage patients with reduced consumption of these resources.

Table 6. Differential cost (NIS per patient) analysis for second study periods

	Oct-Dec 2023	Oct-Dec 2022	Difference
Laboratory studies	-1,101	-1,016	8%
Imaging and Diagnostic Procedures	-1,300	-1,149	13%
Consultations	-93	-109	-15%
Medical stuff	-6,601	-6,134	8%
Nursing stuff	-3,096	-3,057	1%
Medications and Consumable Supplies	-1,634	-1,979	-17%
Total	-13,825	-13,443	3%

The second period demonstrate a modest increase in the cost of 3%, from 13,443 ILS to 13,825 ILS, representing an additional cost of 382 ILS per patient. This increase was significantly lower than the rise observed in the first study period. This phenomenon may be attributed to several factors. First, the variation in occupancy was lower, and the length of hospitalization was shorter compared to the previous period. However, it is evident that the main difference between the periods lies in the medical and nursing hospitalization categories, which are highly sensitive to occupancy and length of stay. In contrast, the other categories remain consistent with the data from the first period.

6. Implications for policy makers

The occupancy rate in internal medicine departments in Israel is significantly higher compared to other countries worldwide. This situation is widely regarded as problematic, and there is a consensus among professionals and policymakers that steps should be taken to reduce the occupancy rate in order to improve the quality of medical care and patient experience. This topic has become a focal point of public and professional discourse, with many policymakers emphasizing the need for actions to improve the conditions in internal medicine departments.

The reasons why a high occupancy rate may pose a problem are rooted in various factors, including the potential for a negative impact on the outcomes of medical care and the patient experience. High occupancy can lead to a reduction of the resources allocated to each patient, resulting in overburden, longer waiting times, less time dedicated to each patient, and an overall decrease in focus and attention to patient care. All of these factors can lead to poorer clinical outcomes and deterioration in the health status of patients.

Reducing the occupancy rate in internal medicine departments has significant economic implications. As highlighted in the previous chapter, reducing the occupancy rate substantially increases the cost per patient, which necessitates a careful consideration of the benefits of such a move in relation to the associated costs.

An important finding from the current study is that, contrary to common belief, reducing the occupancy rate does not necessarily lead to significant improvements of treatment quality as measured by survival rates. Given the high economic costs involved in reducing occupancy rates, it seems there is no justification for a blanket reduction in occupancy in internal medicine departments solely for the purpose of improving care quality.

However, our results suggest that reducing occupancy rates in internal medicine departments benefits specific groups of patients, particularly those with complex medical conditions. In this context, it may be worthwhile to consider treating complex patients in one internal medicine department while maintaining low occupancy, thereby allowing for optimal resource management and the attention necessary for high quality care for this patient group.

This study suggests that policies aimed at improving patient survival rates in internal medicine divisions should prioritize resource allocation to intensive care units (ICUs) or wards rather than uniformly increasing capacity across general internal medicine departments.

In Israel’s healthcare system, each internal medicine department includes a small unit dedicated to patients requiring intensive respiratory or hemodynamic support - a unique local model that remains a subject of debate among healthcare professionals. ICU specialists argue that these patients receive suboptimal care due to their placement within general internal medicine departments and should instead be treated in a dedicated intermediate-care unit. Our findings indicate that centralizing these patients in a single, well-resourced department may enhance the quality of care, albeit at the cost of reducing resource availability for other patients.

7. Summary

In this study, we use administrative data from large Israeli hospital in two distinct events of rapid unexpected reduction in bed occupancy for causal inference of impact on patients' mortality. Using Difference-in-difference methodology with controls for key patient's metrics such as Norton and Charlston indexes and prior hospitalization history, we do not find robust significant effect of occupancy on patient mortality within 30 days of hospitalization, albeit the relevant coefficients hint to some benefit to patients. These results are not aligned with existing literature that reported that high bed occupancy rates are associated with increased mortality rates.

Our results regarding mortality covariates are consistent with other recent literature that examined the effect of the first waves of the COVID-19 pandemic on mortality of non-Covid patients. Interestingly, in these studies as well, the mortality rate of these patients during periods of low bed occupancy was high (13-17). This can be attributed to the significant allocation of resources to the treatment of COVID-19 patients, resulting in a shortage of resources for other patients. Additionally, patients may have delayed seeking hospital care due to fear of infection, thereby worsening their condition. In RHCC, the burden of COVID-19 patients in hospitals during both study periods was low, and therefore only the second explanation can be relevant.

We find stronger evidence for the benefit of low bed occupancy for ICU admitted patients or those transferred to the unit after admission. These findings have far-reaching policy implications, suggesting that in order to improve patients' survival rates, allocation of capacity should be differential, with provision of more resources to smaller groups of higher medical risk patients.

The validity of our results is supported by the direction and magnitude of the mortality covariates reported in existing literature. Women had a lower risk of death within 30 days (23). Additionally, the Charlson Comorbidity Index (24) and the Norton Score (25) were found to be associated with mortality (the former directly and the latter inversely). Polypharmacy was not found to be consistently correlated with the odds of mortality (26-27). However, a history of previous hospitalization was found to be directly associated with mortality (28). These findings strengthen the main findings in our study regarding the relationship between occupancy rate and mortality.

Our study has several limitations. First, it is a retrospective study and both periods we explore contained large external disruptions, which can affect patient mortality. The ideal framework for examining the research question is a direct prospective comparison in two scenarios (i.e. two arms). One scenario where the occupancy rate in the departments is at the usual capacity in the State of Israel. In the second scenario, there will be a deliberate reduction in the occupancy rate, in fixed stages. However, such a scenario is not feasible in the budgetary and legal reality of the health system. Second, although our data is comprehensive and includes two different periods, there is a potential benefit to widen the research to several hospitals in the country, and medical centers belonging to different networks (governmental, Clalit Health Services, and other public hospitals). Since this is a question of interest for policymakers, it is worth examining it in a national setting. Third, we examined the overall mortality rate in the internal medicine division of the hospital. There is scope to examine the question in other divisions (i.e. surgery, pediatrics, and gynecology) and in additional disease states. Finally, our metric is quantitative and while we believe that resource allocation should be driven by reducing mortality, we suggest also considering patient experience during hospitalization.

References

1. Madsen F, Ladelund S, Linneberg A. High levels of bed occupancy associated with increased inpatient and thirty-day hospital mortality in Denmark. Health Aff (Millwood). 2014;33(7):1236-44.

2. Sharma N, Moffa G, Schwendimann R, Endrich O, Ausserhofer D, Simon M. The effect of time-varying capacity utilization on 14-day in-hospital mortality: a retrospective longitudinal study in Swiss general hospitals. BMC Health Serv Res. 2022;22(1):1551.

3. Castagna F, Xue X, Saeed O, Kataria R, Puius YA, Patel SR, et al. Hospital bed occupancy rate is an independent risk factor for COVID-19 inpatient mortality: a pandemic epicentre cohort study. BMJ Open. 2022;12(2):e058171.

4. Bosque-Mercader L, Siciliani L. The association between bed occupancy rates and hospital quality in the English National Health Service. Eur J Health Econ. 2023;24(2):209-36.

5. Gray WK, Navaratnam AV, Day J, Heyl J, Hardy F, Wheeler A, et al. Role of hospital strain in determining outcomes for people hospitalised with COVID-19 in England. Emerg Med J. 2023;40(8):542-8.

6. Nunez I, Soto-Mota A. Impact of healthcare strain on access to mechanical ventilation and mortality of hospitalized COVID-19 patients: a retrospective cohort study. Trans R Soc Trop Med Hyg. 2023;117(5):383-90.

7. Boden DG, Agarwal A, Hussain T, Martin SJ, Radford N, Riyat MS, et al. Lowering levels of bed occupancy is associated with decreased inhospital mortality and improved performance on the 4-hour target in a UK District General Hospital. Emerg Med J. 2016;33(2):85-90.

8. Kazakova SV, Baggs J, Parra G, Yusuf H, Romano SD, Ko JY, et al. Declines in the utilization of hospital-based care during COVID-19 pandemic. J Hosp Med. 2022;17(12):984-9.

9. Birkmeyer JD, Barnato A, Birkmeyer N, Bessler R, Skinner J. The Impact Of The COVID-19 Pandemic On Hospital Admissions In The United States. Health Aff (Millwood). 2020;39(11):2010-7.

10. Splinter MJ, Velek P, Ikram MK, Kieboom BCT, Peeters RP, Bindels PJE, et al. Prevalence and determinants of healthcare avoidance during the COVID-19 pandemic: A population-based cross-sectional study. PLoS Med. 2021;18(11):e1003854.

11. Rhodes JH, Santos T, Young G. The Early Impact of the COVID-19 Pandemic on Hospital Finances. J Healthc Manag. 2023;68(1):38-55.

12. Alharbi A, Almana RS, Aljuaid M. The impact of COVID-19 pandemic on key performance indicators in three Saudi hospitals. PLoS One. 2023;18(5):e0285616.

13. French G, Hulse M, Nguyen D, Sobotka K, Webster K, Corman J, et al. Impact of Hospital Strain on Excess Deaths During the COVID-19 Pandemic - United States, July 2020-July 2021. MMWR Morb Mortal Wkly Rep. 2021;70(46):1613-6.

14. Garcia-Ptacek S, Xu H, Annetorp M, Jerlardtz VB, Cederholm T, Engstrom M, et al. Temporal trends in hospitalizations and 30-day mortality in older patients during the COVID pandemic from March 2020 to July 2021. PLoS One. 2023;18(9):e0291237.

15. Yousufuddin M, Yamani MH, Kashani KB, Zhu Y, Wang Z, Seshadri A, et al. Characteristics, Treatment Patterns, and Clinical Outcomes After Heart Failure Hospitalizations During the COVID-19 Pandemic, March to October 2020. Mayo Clin Proc. 2023;98(1):31-47.

16. Twohig PA, Scholten K, Schissel M, Brittan K, Barbaretta J, Samson K, et al. Mortality Increased Among Hospitalized Patients with Cirrhosis Before and Following Different Waves of the COVID-19 Pandemic. Dig Dis Sci. 2023;68(12):4381-8.

17. Bodilsen J, Nielsen PB, Sogaard M, Dalager-Pedersen M, Speiser LOZ, Yndigegn T, et al. Hospital admission and mortality rates for non-covid diseases in Denmark during covid-19 pandemic: nationwide population based cohort study. BMJ. 2021;373:n1135.

18. McLarty J, Litton E, Beane A, Aryal D, Bailey M, Bendel S, et al. Non-COVID-19 intensive care admissions during the pandemic: a multinational registry-based study. Thorax. 2024;79(2):120-7.

19. Lemke M, Allen L, Samarasinghe N, Vogt K, Brackstone M, Zwiep T. Impact of COVID-19 Pandemic on Readmission Rates Following Colorectal Surgery: A Retrospective Cohort Study. World J Surg. 2023;47(9):2103-12.

20. Sabbatini AK, Robicsek A, Chiu ST, Gluckman TJ. Excess Mortality Among Patients Hospitalized During the COVID-19 Pandemic. J Hosp Med. 2021;16(10):596-602.

21. Lau VI, Dhanoa S, Cheema H, Lewis K, Geeraert P, Lu D, et al. Non-COVID outcomes associated with the coronavirus disease-2019 (COVID-19) pandemic effects study (COPES): A systematic review and meta-analysis. PLoS One. 2022;17(6):e0269871.

22. Cannata A, Watson SA, Daniel A, Giacca M, Shah AM, McDonagh TA, et al. Impact of the COVID-19 pandemic on in-hospital mortality in cardiovascular disease: a meta-analysis. Eur J Prev Cardiol. 2022;29(8):1266-74.

23. Wu KY, Wang X, Youngson E, Gouda P, Graham MM. Sex differences in post-operative outcomes following non-cardiac surgery. PLoS One. 2023 Nov 1;18(11):e0293638.

24. Frenkel, W. J., Jongerius, E. J., Mandjes-van Uitert, M. J., van Munster, B. C., & de Rooij, S. E. (2014). Validation of the Charlson Comorbidity Index in acutely hospitalized elderly adults: a prospective cohort study. *Journal of the American Geriatrics Society*, *62*(2), 342–346.

25. Trostchansky, I., Nimrod, A., Tiberiu, E., Vigorita, V., Valiñas, R., & Karp, G. (2019). Is Norton Score a useful tool for identifying high-risk patients prior to emergency surgery?. *ANZ journal of surgery*, *89*(4), 362–366.

26. Chang, T. I., Park, H., Kim, D. W., Jeon, E. K., Rhee, C. M., Kalantar-Zadeh, K., Kang, E. W., Kang, S. W., & Han, S. H. (2020). Polypharmacy, hospitalization, and mortality risk: a nationwide cohort study. *Scientific reports*, *10*(1), 18964.

27. Li, Y., Zhang, X., Yang, L., Yang, Y., Qiao, G., Lu, C., & Liu, K. (2022). Association between polypharmacy and mortality in the older adults: A systematic review and meta-analysis. *Archives of gerontology and geriatrics*, *100*, 104630.

28. Loreggian, L., Giorgini, F., Zakaria, A. S., Fanchini, M., Veronelli, A., Pontiroli, A. E., & Tagliabue, E. (2022). Baseline conditions and nutritional state upon hospitalization are the greatest risks for mortality for cardiovascular diseases and for several classes of diseases: a retrospective study. Scientific reports, 12(1), 10819.

Appendix A – Informational Technology Systems

NMR System:

The administrative system at RHCC, referred to as the **NMR System**, is designed to manage the medical administrative information of patients and is based on the ERP infrastructure provided by SAP. This system complies with the highest international standards for systems of its kind and is intended for the efficient management of medical and administrative data within the hospital environment. The NMR system records essential demographic information of patients, including address, health insurance provider, marital status, date of birth, and other relevant details. Upon a patient's admission to the hospital—whether to the emergency department, inpatient care, or outpatient clinics—a unique identifier, the **CASE NUMBER**, is generated to ensure precise identification of each visit. Additionally, the NMR system manages transitions between different care units during the patient's hospitalization, extending through to their final discharge.

Prometheus System:

The clinical system at RHCC, **Prometheus**, is an advanced Electronic Health Records(HER), developed for the purpose of recording all medical information pertaining to the patient throughout their hospital stay. The system was developed locally at RHCC and is based on state-of-the-art technologies, providing healthcare professionals with comprehensive tools for the delivery of high-quality, targeted medical care.

The Prometheus system continuously records medical data by various healthcare providers, including physicians, nurses, physiotherapists, social workers, and other professionals. The documented information includes, among other things, clinical signs and measurements, visit summaries, consultations, surgical procedures, test results from medical labs, medications administered, and treatment instructions. The system enables efficient and rapid access to patient medical information while ensuring high levels of accuracy, thus facilitating enhanced care quality and precise monitoring of the patient’s medical condition.

Data Type	**Source**
Case Number	**NMR**
Admission Date	**NMR**
Discharge Date	**NMR**
Diagnosis	**Prometheus**
Patient ID Number	**NMR**
Gender	**NMR**
Religion	**NMR**
Marital Status	**NMR**
Date of Death	**NMR - Data Updated from the Ministry of the Interior**
Deceased Status	**NMR - Data Updated from the Ministry of the Interior**
Insurer	**NMR**
Emergency Admission Marker	**NMR**
Type of Discharge	**NMR**
Initial Hospitalizing Department	**NMR**
Discharging Department	**NMR**
Charlson Index	**Calculation - Detailed in Charlson Sheet**
Norton Score at Admission	**Prometheus - Detailed in Norton Sheet**
ICU Admission Days	**NMR - Number of ICU Bed Days (Night Stays) for the Patient**
Number of Regular Medications	**Prometheus**
Previous Admissions	**NMR - Admission to Internal Medicine,**

Data Type	**Source**
within Six-Month Window	**Cardiology, Neurology Departments within Six Months Post-Discharge**
Tests in Specialized Departments	**Prometheus - Tests in Gastroenterology, Imaging, Nuclear Medicine, Echocardiography, Invasive Cardiology**
Physician Consultations	**Prometheus**
Readmission within 30 Days	**NMR**