Determinants of length of stay in a tertiary University Hospital

Los determinantes de la estancia hospitalaria en un hospital universitario de alta complejidad

Os determinantes da permanência hospitalar em um hospital universitário de alta complexidade

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Abstract

Objective: To establish and quantify the determinants of hospital stay in a high complexity university hospital in Medellin between 2013 and 2018, assess their importance, and model the expected length of stay. **Methodology:** Retrospective analytical observational study of aggregate data. While following the method step by step, seven models were used, where mean hospital stay was the dependent variable and the respective independent variables were complexity, timeliness of diagnostic procedures, availability of supplies, cases of prolonged stay and financial capacity. The best model was selected using the Akaike and Bayesian information criterion, along with measures of both overall significance and individual significance of the coefficients. Statistical tests of model validity were performed and standardized coefficients were calculated. **Results:** The mean values of the most relevant variables and their standard deviation (SD) were: mean hospital stay, 8.09 days (SD = 0.40); complexity by resource consumption, 1.28 units (SD = 0.07); diagnostic procedures, 90.74 thousand studies (SD = 10.05); cases of extremely prolonged stay, 4.36% (SD = 0.70), and complexity by casuistry, 1 (SD = 0.03). Overall significance: F = 55.2, p < 0.001. Significance of coefficients: complexity by resource consumption, p < 0.01; diagnostic procedures and cases of extremely prolonged stay, p < 0.001; complexity by casuistry, p < 0.05. Standardized coefficients: complexity by resource consumption, 0.35; diagnostic procedures, 0.35; cases of extremely prolonged stay, 0.26; and complexity by casuistry, 0.24. Adjusted R2 0.82. Conclusion: In order of importance, the determinants of hospital stay are complexity by resource consumption, diagnostic procedures, extremely prolonged stay, complexity by casuistry, available inventory and gross profit.

---------*Keywords:* health resource management, hospital management, diagnosis-related groups, hospitalization, statistical models

Resumen

Objetivo: Establecer y cuantificar los determinantes de la estancia hospitalaria en un hospital universitario de Medellín de alta complejidad de Medellín, entre 2013 y 2018, valorar su importancia y modelar la estancia esperada. **Metodología:** Estudio observacional analítico retrospectivo de datos agregados. Siguiendo el método paso a paso, se corrieron siete modelos con estancia hospitalaria media como variable dependiente y las respectivas variables independientes: complejidad, oportunidad de apoyos diagnósticos, disponibilidad de insumos, casos de estancia prolongada y capacidad financiera. Se seleccionó el mejor modelo usando los criterios de ajuste Akaike e información Bayesiana, junto con las medidas de significancia global y significancia individual de los coeficientes. Se realizaron pruebas estadísticas de validez del modelo y se calcularon los coeficientes estandarizados. **Resultados:** Los valores medios de las variables más relevantes y su desviación estándar (DE) fueron: estancia hospitalaria media, 8,09 días (DE = 0,40); complejidad por consumo de recursos, 1,28 unidades (DE = 0,07); apoyos diagnósticos, 90,74 mil estudios (DE = 10,05); casos de estancia extrema, 4,36 % (DE = 0,70), y complejidad por casuística, 1 (DE = 0,03). Significancia global F = 55,2, $p < 0{,}001$. Significancia de los coeficientes: complejidad por consumo de recursos, $p < 0{,}01$; apoyos diagnósticos y casos de estancia extrema, $p < 0{,}001$; complejidad por casuística, $p < 0{,}05$. Coeficientes estandarizados: complejidad por consumo de recursos, 0,35; apoyos diagnósticos, 0,35; casos de estancia extrema, 0,26, y complejidad por casuística, 0,24. R^2 ajustado 0,82. **Conclusión:** Los determinantes de la estancia hospitalaria en orden de importancia son: complejidad por consumo de recursos, apoyos diagnósticos, casos de estancia extrema, complejidad por casuística, inventario disponible y ganancias brutas.

---------*Palabras clave:* administración de recursos de salud, administración hospitalaria, grupos relacionados de diagnóstico, internación hospitalaria, modelos estadísticos.

Resumo

Objetivo: Estabelecer e quantificar os determinantes da permanência hospitalar em um hospital universitário de alta complexidade de Medellín, entre 2013 e 2018, valorar sua importância e fazer a modelação da permanência esperada. **Metodologia:** Estudo observacional analítico retrospectivo de dados agregados. Seguindo o método passo a passo, foram aplicados sete modelos com permanência hospitalar média como variável dependente e as respectivas variáveis independentes: complexidade, oportunidade de apoios diagnósticos, disponibilidade de insumos, casos de permanência prolongada e capacidade financeira. Selecionou-se o melhor modelo usando os critérios de ajuste Akaike e informação Bayesiana, junto com as medidas de significância individual dos coeficientes. Realizaram-se provas estatísticas de validade do modelo e calcularam-se os coeficientes padronizados. **Resultados:** Os valores médios das variáveis mais relevantes e seu desvio-padrão (DP) foram: permanência hospitalar média, 8.09 dias (DP = 0,40); complexidade por consumo de recursos, 1,28 unidades (DP = 0,07); apoios diagnósticos, 90,74 mil estudos (DP = 10,05); casos de permanência extrema, 4,36 % (DP = 0,70), e complexidade por casuística, 1 (DP = 0,03). Significância global F = 55,2, $p < 0{,}001$. Significância dos coeficientes: complexidade por consumo de recursos, $p < 0{,}01$; apoios diagnósticos e casos de permanência extrema $p < 0{,}001$; complexidade por casuística, $p < 0{,}05$. Coeficientes padronizados: complexidade por consumo de recursos, 0,35; apoios diagnósticos, 0,35; casos de permanência extrema, 0,26 e complexidade por casuística, 0,24. R2 ajustado 0,82. **Conclusão:** Os determinantes da permanência hospitalar em ordem de importância são: complexidade por consumo de recursos, apoios diagnósticos, casos de permanência extrema, complexidade por casuística, inventário disponível e lucros brutos.

----------*Palavras-chave:* administração de recursos de saúde, administração hospitalar, grupos relacionados de diagnóstico, internação hospitalar, modelos estatísticos

Introduction

A health system, as an institutional arrangement, is designed to achieve three primary objectives: improving the health of the population, ensuring access to health services, and providing financial protection. Hospitals, as key actors in this arrangement and given prevailing health regulatory conditions, participate in a highly competitive and regulated market, which challenges them to use resources efficiently. Estimates indicate that hospitals allocate between 42 and 46% of their total expenditure to hospital logistics. Consequently, ensuring enhanced coverage and accessibility by adequately managing these resources is a significant challenge [1].

Hospital discharges are the primary output for hospitals. They encompass a range of intermediate products such as consultations, medicines, procedures, therapies, hospitalization, and materials, in addition to support services like laundry, food, linen, sterilization, and administrative services. These are all intricate to obtain [2].

Based on the patient's morbidity, associated comorbidities, type of treatment, and needs during hospitalization, the cost of stay can constitute 35 to 68% of the total hospitalization costs [3,4].

The *length of stay* is one of the most closely monitored indicators of efficiency and quality in hospitals and health systems. It comprises the days from a patient's admission to discharge, and corresponds to the time needed for the patient to transition from an acute phase to continue with out-of-hospital management [5,6].

A stay that exceeds a specific reference value is considered *prolonged*. A prolonged stay can lead to adverse events from extended hospitalizations and increased costs for the health system. Reducing the length of stay is a primary objective for hospitals, especially when striving to maintain quality standards that align with the hospital's complexity. Achieving this not only increases effective bed capacity, granting the population broader access to hospitalization services, but also streamlines bed resource utilization, and facilitates a more rational and equitable allocation of expenses across all health determinants [5,7-10].

As the length of stay is one of the main drivers of hospital production, it is important for hospitals, the health system, and public health to address its study. The objective is to understand the factors that determine the length of stay and take measures to ensure it aligns with the population's morbidity conditions and healthcare needs [11-13].

Based on the reviewed literature, significant factors influencing the length of stay include social conditions, age, sex, complexity of the hospitalization unit, certain administrative aspects, diagnosis, disease severity, cases of extreme length of stay, timeliness of diagnostic and therapeutic supports, timeliness of the treatment, availability of technology, timeliness of interconsultations and surgeries, adverse events, comorbidities, discharge procedures, early discharges for home-based care, health insurance, and the adequacy of hospital resources, among others [10,14-16].

Although no studies were found that incorporated or modeled financial variables to explain the length of stay, it was of interest to study whether these constitute a significant factor. Such variables were: variation in the hospital's gross profit (Ebitda), monetary collection and financial situation of the institution, among others, in addition to non-financial variables, such as: complexity, timeliness of diagnostic aids, available supplies, and cases of prolonged or extreme length of stay.

This study assumes the premise that financial stability propels institutional operations (as in any business), by ensuring a timely, constant and adequate flow of resources (cash flow) that guarantees: medicines, devices, supplies, infrastructure, maintenance and support services, and so forth. With such a dynamic operation, hospital stay would inversely correlate with available resources. In other words, an increase in resources, driven by financial dynamics, would likely result in reduced lengths of stay [10,14,17].

For the analysis of length of stay, different variables studied have been approached from the perspective of *diagnosis-related groups* (DRG). This widely used tool classifies patients into groups based on clinically similar diagnoses and comparable resource use, and succinctly provides insights into the hospital's case mix and its complexity, as well as data for analyzing the length of hospital stays and the intensity of resource use [18,19].

Therefore, the objectives of this research were to establish and quantify the determinants of length of stay at a tertiary university hospital in Medellín from 2013 to 2018, assess their importance, and model the expected length of stay.

Methodology

A retrospective, analytical, observational study was conducted using a non-probabilistic purposive sampling based on the behavior of the average length of stay over a 72-months period from 2013 to 2018. Hospital indicators, serving as an aggregate summary measure of hospital activity, were integrated into the research.

Regarding the length of stay and certain study variables, the following relationships were assumed: a direct relationship with complexity (an increase in the factor corresponds to a longer stay, and vice versa), an inverse relationship with timeliness, available inventory, and financial capacity (an increase in the factor corresponds to a shorter stay, and vice versa), and a direct relationship with failures in logistical and administrative processes [15].

In our study, factors affecting length of stay were grouped into six broad categories: complexity of the disease (for this study, resource use complexity and case mix complexity), timeliness of diagnostic and therapeutic aids, availability of care supplies, timeliness of medical decision-making, timeliness of logistical and hospital processes, and financial capacity.

Definition of Variables, Measures and Possible Relationship with Length of Stay

Based on the factors mentioned in the literature, the average length of stay indicator (in days) (ED) was calculated as the dependent variable, which is explained by the following independent variables (hospital indicators used as an aggregate summary measure of hospital activity):

COMCORE: COMCORE: *Resource Use Complexity* (expressed in units). Represents the relative average of resource consumption among different DRGs in the hospital compared to the average consumption of the standard hospital patient or the comparison referent. A value greater than 1 indicates that the resource use (and therefore the complexity) in the DRG is higher than that of the standard hospital patient or comparison referent, which implies a longer average length of stay, and vice versa.

COMCA: *Case Mix Complexity* (expressed in units). Indicates the relative complexity of the mix of patients (case mix) treated in comparison to a designated standard of complexity. It takes into account factors such as the severity of the disease, complications arising from care, prognosis, treatment difficulty, and the extent of medical intervention required. A value greater than 1 indicates a case mix that is more complex than the standard, typically leading to a longer average length of stay, and vice versa. The value for this variable will always be greater than zero.

APOYOS: *Diagnostic Aids* (expressed in numbers). Serves as a proxy variable for the timeliness (response times) of imaging and laboratory aids. For ease in calculations and interpretations, a factor of one thousand units of the original measurement was taken as one unit of the variable. Increasingly higher values imply worse response times and increases in the average length of stay.

CAESEX: *Cases of Extreme Length of Stay* (expressed in percentage points). Represents the proportion of patients who are statistically above the upper cut-off point of all discharges analyzed. It includes medical, logistic, administrative, and external aspects. Consequently, higher proportions directly correspond to longer lengths of stay.

QUIRÓFANO: *Operating Room Occupancy* (expressed in percentage). Proxy variable for surgical timeliness (response times). It measures intensity of use as a proportion of available operating room time. Increasingly higher proportions close to 100% imply worse response times and an increase in the average length of stay

INVENTARIO: *Available Inventory* (expressed in days). Represents the average number of days for which supplies, including medications, medical devices, surgical materials, and general supplies, are available. Days of supply correspond, on average, to the coverage of needs in hospitalization services. Longer days of availability of supplies correlates to a shorter average length of stay.

Ebitda: *Gross Profit* (variation in percentage points). Serves as a proxy variable for the generation of cash (money available for immediate use), which indicates the hospital's capacity to maintain operations with resources from core hospital activities. Higher positive variations imply higher cash generation and a decrease in the average length of stay.

SUFICIENCIA: *Adequacy of Cash Collection* (expressed in units). Measures the capacity of cash to cover operating expenses that also involve cash outflows (labor, purchases, overhead, and more). A value greater than 1 indicates that cash collection sufficiently exceeds cash outflows. Increasing values lead to a decrease in the average length of stay.

EFECTIVO: *Monetary Collection* (millions of pesos). Represents the cash inflow from the sale of health services. For ease in calculations and interpretations, one billion pesos from the original measurement was taken as one unit of the variable. Increases in the variable indicate higher cash receipts and a decrease in the average length of stay.

RESULTADO: *Economic Results*. This is a dichotomous variable with values set as: 1 = profit period (January 2013 to June 2016); 0 = loss period (July 2016 to December 2018). The significance of this variable lies in evaluating how the periods of profit or loss impact the length of stay from a financial standpoint. The reference value is 1 and allows us to identify the differences in the length of stay that may occur from one period to another.

Statistical Analyses

For the calculation of hospital indicators in this study, we utilized primary data generated in the institution, drawn from different application databases.

To gather information on average length of stay, COMCA, COMCORE, and CAESEX, we utilized the minimum basic data set (CMBD-GRD), sourced from the clinical history records of each patient (SAP 6.0 EHP 8® information system). This data was then processed using the GRD ALCOR-GRD® system, version 2.3. For the calculation of other indicators, the information was directly extracted from the SAP 6.0 EHP 8 information system. These systems were licensed by the tertiary hospital.

All indicators were archived in the Visión Empresarial Suite System, version 9.6.32®. For statistical processing, we employed the Jamovi software, version 2.3 (2022), which is a free, open-source statistical platform. We did not utilize any external databases.

During data collection, quality controls were implemented to minimize risks of non-compliance with essential attributes for adequate processing such as accuracy, completeness, integrity, updating, coherence, relevance, accessibility, and reliability. In addition, the applications were equipped with IT security mechanisms, including availability, integrity, confidentiality, and authentication.

Since the average length of stay is continuous, its conditional mean or expected value was modeled with the respective explanatory variables. This was done through a regression equation of the type

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k + u, \qquad \text{(Ecuación 1)}$$

as a way to approximate the phenomenon. The estimation was achieved using ordinary least squares [20,21].

For variable inclusion, a bivariate analysis was performed using the correlation matrix of length of stay with the continuous variables (ED, COMCORE, COMCA,

APOYOS, CAESEX, QUIRÓFANO, INVENTARIO, Ebitda, SUFICIENCIA y EFECTIVO), and the Student's t-test with the dichotomous variable (RESULTADO), choosing those with significance of $p < 0{,}1$ [20].

The normality of the average length of stay was verified. We adjusted the model using the stepwise method and excluded variables that did not collectively enhance the Akaike and Bayesian information criteria, the mean squared error, or the individual significance of the coefficients (with $p < 0.1$). We calculated the adjusted R^2 and the F test for the overall model. Additionally, we validated the assumptions of the classic regression model: homoscedasticity (Breusch-Pagan test), non-multicollinearity (variance inflation factor), no autocorrelation (Durbin-Watson statistic), and normality of the residuals (Shapiro-Wilk test). Lastly, with the estimated parameters, we modeled the expected or conditional length of stay by setting different values for the independent variables to predict the dependent variable (the expected length of stay) [20].

Ethical Aspects

This study received approval from the Research and Innovation Committee of Universidad CES's Faculty of Medicine (Act 257, April 21, 2021) and from the Research Ethics Committee of the hospital under study (Act 16-2021, June 11, 2021).

Results

In order to establish and quantify the determinants associated with length of stay, a bivariate analysis was performed, which yielded seven explanatory variables with a significant relationship: resource use complexity, diagnostic aids, cases of extreme length of stay, case mix complexity, available inventory, gross profit and economic results, all with $p < 0.05$, thus suggesting their incorporation into the model.

The seven variables were incorporated one by one, and then model six was selected as it complied with the methodological approach. At this point, the variable RESULTADO was discarded due to its p-value being greater than 0.1 (see Tables 1 and 2).

Table 1. Descriptive statistics of the variables of the final model (N = 72)

	Description	Average	SD
ED	Average length of stay	8.09	0.41
COMCORE	Resource use complexity	1.28	0.07
APOYOS	Diagnostic aids	90.74	10.05
CAESEX	Cases of extreme length of stay	4.36	0.70
COMCA	Case mix complexity	1	0.03
INVENTARIO	Available inventory	24.46	4.54
Ebitda	Gross profit	31.85	160.14

Table 2. Adjustment measures following the stepwise method

Model N = 72	Adjusted R^2	AIC	BIC	RMSE	F
1	0.65	4.90	11.73	0.240	128.5
2	0.73	−14.10	−5.05	0.207	96.9
3	0.80	−32.26	−20.95	0.180	91.9
4	0.80	−34.04	−20.47	0.175	72.5
5	0.82	−37.55	−21.71	0.168	62.8
6	0.82	−39.65	−21.55	0.164	55.2
7	0.82	−38.10	−17.80	0.163	46.9

AIC: Akaike information criterion; BIC: Bayesian information criterion; RMSE: Root-mean-square error;

F: Significance test for the model.

In the end, with six definitive variables, the equation of the model to be estimated was:

where u is the random variable of the model

$$ED = \beta_0 + \beta_1\text{COMCORE} + \beta_2\text{APOYOS} + \beta_3\text{CAESEX} + \beta_4\text{COMCA} + \beta_5\text{INVENTARIO} + \beta_6\text{Ebitda} + u, \quad \text{(Ecuación 2)}$$

Validation of the Assumptions of the Classical Regression Model

The statistical tests, as per the analysis plan, yielded: homoscedasticity, non-multicollinearity, non-autocorrelation and normality of the residuals. These collectively guarantee the statistical reliability of the model, lending robustness to the conclusions derived from it [20].

Statistics of the Model

The estimation yielded four variables with significance of $p < 0.05$ and two variables with $0.05 < p < 0.1$. The model as a whole was significant, with $F = 55.2$ and $p < 0.05$.

Based on the standardized coefficients, the variables with the greatest impact were: resource use complexity, diagnostic aids, cases of extreme length of stay and case mix complexity. Conversely, the variables with the least impact were: available inventory and gross profit. The adjusted R^2 indicated that variations in length of stay are 82% produced by variations in the model's explanatory variables. The signs of the coefficients aligned with the proposed analysis.

These results indicate that for each one-unit increase in resource use complexity, the length of stay increases by 2.16 days; in diagnostic aids, it increases by 0.01 days; in cases of extreme length of stay, it increases by 0.15 days, and in case mix complexity, it increases by 3.94 days. Conversely, for each one-unit increase in available inventory, the length of stay decreases by 0.01 days, and in gross profit, it decreases by 2.66e-4 days (see Table 3).

Table 3. Coefficients of the model with 95% confidence interval

Variable	Coefficient βi	95% confidence interval	Standardized coefficient (βi)
Constant	−0.31	(−2.37-1.76)	
COMCORE	2.16**	(0.86-3.51)	0.35
apoyos	0.01***	(0.01-0.02)	0.35
CAESEX	0.15***	(0.09-0.22)	0.26
COMCA	3.94*	(0.70-7.15)	0.24
INVENTARIO	−0.01	(−0.02-6.80e−4)	−0.12
Ebitda	−2.66e−4	(−5.39e−4-6.47e−6)	−0.10

Statistical significance: *p < 0,05, ** < 0.01, ***p < 0,001. INVENTARIO and Ebitda variables with $0.05 < p < 0.1$

The equation with the estimated coefficients was:

$$ED = -0.31 + 2.16COMCORE + 0.01APOYOS + 0.15CASESEX + 3.94COMCA - 0.01INVENTARIO - 0.0003Ebitda. \quad \text{(Ecuación 3)}$$

Modeling of expected length of stay

One of our primary aims was to establish a method to calculate the expected length of stay based on different values of the explanatory variables. Using Equation 3 with the average values of the explanatory variables (baseline), and targeting a half-day reduction in length of stay, assuming changes in diagnostic aids, cases of extreme length of stay, available inventory, and Ebitda, the length of stay would shift from 8.09 days to 7.64 days (assuming other variables remain constant) (see Table 4)

Similarly, with the same baseline but with an increase in resource use complexity to 1.38 and in case mix complexity to 1.05 (assuming other variables remain constant), the length of stay would rise by 0.41 days, leading to a new average of 8.5 days.

Discussion

It is essential for health systems to ensure greater accessibility to hospitalization services to facilitate the recovery of patients with acute conditions and enhance overall health. While all determinants of health - including lifestyles, human biology, the health system, and the environment - necessitate the allocation of government resources, it is the health system that consumes the majority of these resources. As a result, researching and implementing strategies to optimize the availability of hospital beds becomes crucial. The goal is to maximize the number of patients treated with a given resource structure while always ensuring the quality and rationality of care.

Table 4. Calculation of expected length of stay based on changes in explanatory variables

Variable	Estimated coefficients	Average values of X_i	Unit of measure of X_i	Desired change in X_i	New value of Xi
COMCORE	2.16	1.28	Unit	0	1.28
APOYOS	0.01	90.74	1 × 1000	−10	80.74
caesex	0.15	4.36	Percentage points	−1.36	3.00
COMCA	3.94	1.00	Unit	0	1.00
INVENTARIO	−0.01	24.46	Unit	10	34,46
Ebitda	−0.0003	31.85	Percentage points	13.15	45.00
Constant	−0.31				
Expected average length of stay	8.09	New length of stay	7.64	Variation	−0.45

In the institution under study, the average length of stay (ED) of 8.09 days is comparable to that reported for other hospitals in the literature, and it falls below the standard of 9 days accepted in other studies. This demonstrates that the institution's performance aligns with some of the best results reported.

The resource use complexity of 1.28 aligns closely with results from other hospitals of a similar tier. For instance, the Hospital de Urgencia Asistencia Pública Dr. Alejandro del Río (HUAP) in Santiago de Chile, reported in 2014 that their average length of stay since 2010 was 8.34 days, with a resource use complexity of 1.12. This report also compared data from 2013 and 2014: while complexity figures were 1.12 and 1.16 for those years respectively, the corresponding average lengths of stay were 5.98 and 6.92 days. This data highlights a clear relationship: as complexity increases, so does the length of stay.

As an example, at the HUAP, the K35 diagnosis (acute appendicitis) with a complexity of 0.85 had an average length of stay of 2.42 days; the S82 diagnosis (leg fracture), which had a complexity of 1.07, resulted in a stay of 8.74 days; the A41 diagnosis, corresponding to other septicemias and having a complexity of 2.31, led to a stay of 17.04 days; and the T29 diagnosis (burns and corrosions affecting multiple body regions), with a complexity of 4.31, resulted in an extended length of stay of 41.16 days. While these figures weren't derived from a model, they certainly provide a glimpse into the relationship that this study discovered between length of stay and complexity.

Again at the HUAP, it was observed that the case mix complexity was 1.16 and 1.12 for the same periods. When compared to our institution's result of one, the HUAP exhibited longer average lengths of stay. Moreover, the percentage of cases with extreme length of stay at our institution was 4.36%, comparable to HUAP's 3.9% for the 2010-2014 period [21].

In 2018, a comparison was made at the Hospital Puerto Montt, Chile, between the resource use complexity of the overall hospital and its maternity service, along with their respective lengths of stay. The hospital's complexity was 0.93 with a length of stay of 7.4 days, while the maternity service's complexity was 0.4 with a length of stay of 3.4 days. This indicated that the maternity service's complexity was 0.43 times that of the overall hospital, and its average length of stay was 0.46 times as long. Notably, maternity services typically exhibit lower complexity, which corresponds with their shorter average lengths of stay [19].

At the Hospital Clínico Universidad de Chile, over a 10-year experience in the implementation of DRGs, the following results were noted: resource use complexity of 0.98; an average length of stay of 3.9 days; a prolonged length of stay of 2.25%; and a case mix complexity of 0.97. When compared to our institution's data, these results were consistently lower, highlighting the direct relationship between complexity and cases of extreme stay with the length of hospital stay [18].

In 2014, a study at the Hospital Pablo Tobón Uribe characterizing hospital discharges with malignant tumors using DRGs found a resource use complexity of 1.62 and an average length of stay of 10.69 days. Comparatively, by 2018, our institution reported similar results for the oncology service, with an average stay of 10.7 days. [2].

In this study, diagnostic aids showed a direct relationship with the length of stay, and an inverse relationship with available inventory. These findings were consistent with other studies. For instance, a study on factors prolonging length of stay conducted in Peru at the Hospital Central de la Policía Nacional Luis N. Sáenz, identified lack of supplies, delays in procedures, laboratory results, x-rays, and special procedures [10].

In several studies using regression techniques, the following results were found:

Jiménez *et al*. (1999) applied a multiple linear regression model with length of hospital stay as the dependent variable for both medical and surgical patients. They found that severity index (complexity) was significant, with $p = 0.000$ and $p = 0.04$, and adjusted R^2 values of 0.41 and 0.7, respectively [22].

In 2019, Casalino *et al*. applied a linear regression model using the length of stay as the dependent variable. They found that disease severity was a significant predictor, with a $p < 0.0001$ and an adjusted R^2 of 0.28 [8].

In 2018, Marfil-Garza et al. applied a logistic regression model to assess the association between prolonged length of stay and complexity variables. They found that bone marrow transplantation (OR 18.39 [IC 95% 12.50-27.05], $p < 0.001$), complex infectious diseases (OR 4.65 [IC 95% 3.40-6.63], $p < 0.001$), and complex abdominal diseases (OR 2.57 [IC 95% 1.98-3.32]) had the highest risk of prolonged length of stay [16].

These studies, modeled with regression methods, support the findings of this research. Specifically, complexity — as indicated by COMCORE (p < 0.01, standardized coefficient = 0.35) and COMCA (p < 0.05, standardized coefficient = 0.24) — is one of the main variables influencing the length of stay.

In a 2016 study conducted by Suasnabar Dávila, using measures of association, a significant relationship was observed between prolonged length of stay and administrative causes (OR = 9.082; 95% CI = 6.066-13.597, $p = 0.000$). These administrative causes primarily consist of delays in the approval of letters of guarantee by insurance agencies, surgical risks, available blood reserves, delays in acquiring necessary materials for surgical procedures, and surgery postponements. As highlighted in our research, the cases of extreme length of stay and inventory (CAESEX with $p < 0.001$ and standardized coefficient 0.26; INVENTORY with $p < 0.1$ and standardized coefficient -0.12) encapsulate many of these issues [23].

While no explicit evidence was found to support the impact of gross profit ($p < 0.1$, standardized coefficient -0.1) on the length of stay, the significance of this indicator in evaluating the operational results of various hospital institutions should be acknowledged. In audits conducted by the Office of the Comptroller General of Medellin, it was observed that the Hospital General de Medellin (HGM) experienced an 87% variation in Ebitda in 2017 compared to 2016, indicating an appropriate generation of resources and a subsequent increase in cash flow. The Hospital Concejo de Medellín reported a negative Ebitda for 2017, reflecting a 24% reduction in loss compared to 2016. This indicates that the hospital's internal results were insufficient to support its operations, and contrary to trends observed at HMG and in our institution, the cash flow saw a drastic reduction. Additionally, the economic report for 2020 from Fundación Santa Fe de Bogotá reported a 32% decrease in Ebitda compared to 2019. These findings related to Ebitda are noteworthy as they highlight its potential to influence hospital operations [24-26].

Not all variables exhibit the same susceptibility to impact in terms of magnitude and timing. Their influence depends on the capacity to identify, prioritize, and devise effective intervention strategies. The model developed in this research facilitates this process quantitatively, underpinned by a rigorous statistical methodology.

Resource use complexity a particularly noteworthy variable that is preferable to maintain at high levels, given that it characterizes tertiary hospitals, such as the one examined in our study. On the other hand, case mix complexity might be a prime target for intervention, especially by enhancing clinical processes, as supported by a report from the Centro Médico Imbanaco, in Cali, Colombia, which reported results of 0.92, 0.9, and 0.85 for the years 2016, 2017, and 2018, respectively [27]. Diagnostic aids can be modulated based on the relevance of prescriptions. Additionally, resource management (available inventory and Ebitda) are sensitive and rapidly changing variables. As such, they require agile and timely intervention.

From the baseline, the model is an inference tool, and its use relies on understanding the variables and the interests of health system stakeholders. While the model provides guidance on areas for impact, the specifics of implementation are left to decision-makers

Limitations

The approach of this study relies on aggregate variables. As such, it does not enable conclusions regarding individual patient characteristics, specific pathologies, or hospital services. This approach limits the potential for detailed insights into more specific aspects.

Using the number of diagnostic aids and gross profit as proxies for the timeliness of diagnostic aids and cash flow, respectively, could bias their true impact on the length of hospital stay, as their actual measurements remain unknown.

As this study is not multicenter, it limits the conclusions to a generalized level for hospital services overall.

Given the lack of studies modeling the impact of available inventory and Ebitda, direct contrasts were not feasible.

Even though the data were from a time series, they were only used to determine factors related to length of stay based on explanatory variables, which could potentially limit other significant findings

Conclusions

In this study, our goal was to identify and quantify the determinants of length of stay at a tertiary university hospital in Medellín, and to assess the relative importance of each determinant.

In order of importance and supported by sufficient evidence, the determinants of length of stay and their relative contribution to the institution analyzed were: resource use complexity, timeliness of diagnostic aids, cases of extreme length of stay, case mix complexity, available inventory, and gross profit (Ebitda) (see Table 3).

It is fundamental to note that this research, in line with other studies, emphasizes that patient complexity has the most significant impact on the length of stay. Factors like disease severity, prognosis, treatment difficulty, and the need for medical intervention, which inherently demand greater resource use, hold considerable weight. Additionally, as hypothesized, the ability to provide resources both timely and consistently—as evidenced by positive Ebitda variations and increased supply availability—can effectively reduce the length of stay.

These findings are of great relevance since, according to the literature reviewed, these variables have not been explicitly incorporated in other statistical regression models.

With the estimated equation (see Equation 3), it was possible to establish a mechanism for calculating the expected length of stay for different values of the explanatory variables, which makes it possible to model action scenarios.

In this study, we employed the multiple linear regression statistical model, which serves as a powerful tool to synthesize the phenomenon under investigation and derive objective quantitative conclusions.

The use of the DRG tool enables management of hospital activities in an aggregate manner, and indicators derived from its analysis support studies aiming to correlate variables such as length of stay in this research.

This research can be replicated in other institutions. Nonetheless, for future studies, it would be interesting to address the study phenomenon at a multicenter level, employing the methodology and objectives outlined here. This would facilitate comparisons and potentially extend the findings to the health system in general.

This opens the door to using this information for time series modeling. This approach could enable the anticipation of possible future results by allowing calculations of the hospital stay value for specific periods, without modeling relationships with explanatory variables.

It is also advisable to conduct studies examining the impact on the length of stay by considering more specific variables. These could be derived from the variables in this and other studies, such as age, diagnosis, comorbidities, socioeconomic conditions, insurance status, geographic location, number of admissions to the institution, actions of insurers, hospitalization unit, and so on. Given this, various research designs could be employed, potentially using methods like logistic regression, Cox regression, panel data, Markov models, among others.

Recognizing that the primary output of a hospital is the medical discharge, which encompasses all intermediate health products, it is essential for institutions to ensure that this clinical 'production' meets the highest quality standards, this study contributes to the clinical management of hospitals by promoting the adoption of similar evaluation criteria for the length of stay. Given that clinical management is in charge of articulating macro processes (like strategy, sustainability, and economic value) and micro processes (such as health benefits, timeliness, and cost) in healthcare institutions, this study aids in achieving their shared objective: generating "clinical value" for the patient.

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Conflict of Interest

The authors declare no conflicts of interest

Statement of Responsibility

The authors take full responsibility for the results and content of the manuscript.

Author Contributions

Darío Alberto Gómez Peña. Conception of the research idea, data collection, results analysis, and manuscript writing.

José Bareño Silva. Project formulation, participation in methodology and results, and review of the final document.

Uriel Palacios Barahona. Review of the project protocol, design adjustments, critical revision, and writing improvement.

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