Healthcare Transformation with Informatics and Artificial Intelligence
J. Mantas et al. (Eds.)

doi:10.3233/SHTI230440

A Regressive Model to Study the Hospitalization for Laparoscopic Appendectomy: A Multicenter Study

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Abstract. Appendicitis is a most common abdominal condition worldwide, and appendectomy especially laparoscopic appendectomy is among the most commonly performed general surgeries. In this study, data were collected from patients who underwent laparoscopic appendectomy surgery at the Evangelical Hospital "Betania" in Naples, Italy. Linear multiple regression was used to obtain a simple predictor that can also assess which of the independent variables considered to be a risk factor. The model with R2 of 0.699 shows that comorbidities and complications during surgery are the main risk factors for prolonged LOS. This result is validated by other studies conducted in the same area.

Keywords. Laparoscopic Appendectomy, LOS, Multiple Linear Regression Model

1. Introduction

Appendectomy is the most commonly performed general surgery procedure [1]. Several studies have demonstrated the effectiveness of the laparoscopic approach both as a reduced risk of complications and in terms of hospital stay [2].

Length of stay (LOS) refers to the number of days a patient remains in the hospital and is therefore directly related to the expense incurred for each patient. In this way, this parameter becomes a direct indicator of the effectiveness and efficiency of hospital resource use [2]. For this reason, several studies have been conducted for the purpose of creating predictive models [4, 5] or for the identification of risk factors [6, 7]. In fact, modern data analysis techniques such as mathematical models [8-10], Fuzzy Logic [11, 12], statistical techniques [13-16] or management methods such as Lean Six Sigma [17] or in support of additive manufacturing [18-20] are increasingly being used in this area.

In this study, we aim to use a linear regression model to study the risk factors that produce increased LOS in patients undergoing laparoscopic appendectomy surgery. The context is the Evangelical Hospital "Betania" in a less wealthy district of Naples (Italy) consisting of 158 beds and a 24-hour emergency department.This study is part of a larger line of research involving other major hospitals in southern Italy such as the University

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Hospital "San Giovanni di Dio e Ruggi d'Aragona" of Salerno [1] and the A.O.R.N. "A. Cardarelli" of Naples [2]. Understanding risk factors could help healthcare management create appropriate pathways for specific classes of patients to achieve LOS that remains constant.

2. Methods

In this article, data of 100 patients who were admitted to the General Surgery Operating Unit of Evangelical Hospital "Betania" for appendectomy surgery (DRG = 164, 165, 166, 167) in 2019-2020 were processed. Using hospital discharge records, the following information was extracted: Date of admission, discharge and main procedure; Main and secondary diagnoses (from these we obtain the variable Comorbidities which is 1 in case of comorbidities such as Obesity, Diabetes, Hypertension / 0); Age; Gender (1 Male / 2 Female); DRG (used to characterize whether the procedure was with complications or not). From the date variables, Pre-Op LOS and LOS was calculated. No exclusion criteria were defined.

2.1. Multiple Linear Regression Model

Multiple linear regression models aim to search for a linear relationship between the dependent variable (LOS) and the independent variables (Age, Gender, Pre-Operative LOS, Comorbidities and Complication during surgery) [21, 22]. To do this, through the method of mean square error minimization, it is necessary to characterize the value of the coefficients β that allow defining this curve. The model thus defined gives the possibility of estimating, minus an error, the LOS from the combination of the independent variables and the coefficients found and determining the main risk factors. To assess whether or not the variable β should be different from 0, the statistical t-test based on averages with a 95% confidence interval is used.

However, the model is not always applicable but one needs to go through hypothesis testing analyzing the properties of the residuals and the presence of outliers. Specifically, Table 1 shows the hypotheses tested, the methodology adopted for verification and the threshold values defined in the literature.

Table 1. Hypotheses underlying the MLR Model.

Hypotheses	Used Methodologies	Threshold [21, 22]
Multicollinearity absence	Tolerance and Variance Inflation Factor (VIF)	Tolerance > 0.2, VIF < 10
Independence of residuals	Durbin-Watson test	(2; 4)
Absence of outliers	Cook's Distance	< 1

3. Results

Before implementing the MLR model, hypotheses were checked to evaluate its applicability. VIF is the reciprocal of Tolerance and are a function of the correlation coefficients between the independent variables. The Cook's distance was for each observation less than 1. Last check is on the correlation of the residuals. The results in terms of Tolerance and VIF, Durbin-Watson test and the performance of the model are shown in Table 2.

Table 2. Tolerance, VIF and analysis of MLR model coefficients and results.

	Tolerance	VIF	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	MLR Model	
			B	Std. rror	Beta				
Intercept	-	-	2.366	0.535	-	4.421	**0.000**	**R**	0.836
Pre-Operative LOS	0.962	1.039	0.906	0.085	0.618	10.716	**0.000**	**R2**	0.699
Comorbidities	0.782	1.279	1.252	0.425	0.189	2.945	**0.004**	**Adjusted - R2**	0.683
Age	0.664	1.506	0.012	0.010	0.081	1.173	0.244	**Std. Error of the Estimate**	1.475
Gender	0.995	1,005	0.069	0.296	0.013	0.233	0.816		
Complication during surgery	0.604	1.656	1.616	0.383	0.307	4.214	**0.000**	**Durbin-Watson**	2.572

Regarding performance, the R2 value above 0.5 shows the goodness of the model in its use in this specific application field [21, 22]. The test output is 2.572 and thus within the acceptable range. Table 2 also reports the coefficient values and the result of the t-test statistic implemented to determine which among the independent variables affects LOS. With the exception of Pre-Op LOS, which is included in LOS by definition, the presence of comorbidities and complications affect the value of the dependent variable. Among these, the greatest impact is related to complications during surgery (highest coefficient). Age and Gender, on the other hand, do not impact LOS by showing no significant differences between men and women or in the older population.

4. Discussion and Conclusion

In this paper, data of patients admitted to Evangelical Hospital "Bethany" for appendectomy surgery in 2019-2020 were processed. The validated and implemented model returned an R2 value of 0.699, which guarantees good performance in the specific field of application.

Comparing the result with what was obtained by the same research group on similar facilities in the territory shows that in this case the performance was significantly better (R^2=0.699 compared with R^2=0.638 [1] and R^2=0.493 [2]). Among the risk factors, however, complications during surgery are in all cases determined in prolonging LOS demonstrating the reliability of the result obtained.

However, our work is not without limitations. Only a linear model is used in this study, and no operational solutions are proposed from the identified risk factors. Future developments include the use of different algorithms, the combined use of data from different hospitals to obtain generalized results to identify appropriate operational actions.

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