Multiple Regression Model to Predict Length of Hospital Stay for Patients Undergoing Femur Fracture Surgery at "San Giovanni di Dio e Ruggi d'Aragona" University Hospital

Teresa Angela Trunfio[1], Arianna Scala[2(✉)], Antonio Della Vecchia[3], Angelo Marra[3], and Anna Borrelli[3]

[1] Department of Electrical Engineering and Information Technology, University of Study of Naples "Federico II", Naples, Italy

[2] School of Medicine, Department of Public Health, University of Study of Naples "Federico II", Naples, Italy
ariannascala7@gmail.com

[3] "San Giovanni di Dio e Ruggi d'Aragona" University Hospital, 84125 Salerno, Italy

Abstract. The economic cuts suffered by public health have in many cases led to the reduction of beds. In order to optimize the available resources, the length of stay (LOS) can be used as an efficiency parameter. The objective of this study is to predict the value of LOS using the clinical information that is generally supplied by a patient who is hospitalized following a fracture of the neck of the femur and to make a comparison with results obtained after the implementation of the new diagnostic-therapeutic-assistance pathway (DTAP). The analysis was conducted on data extrapolated from the information system of the University Hospital "San Giovanni di Dio and Ruggi d'Aragona" of Salerno (Italy). The results show promising outcome in the use of the proposed prediction models as a tool for determining an estimate of the LOS and support the decision making process and the management of hospital resources in advance. In addition, the comparison of between the two models can be used as an indicator to assess the efficiency of the implemented DTAP.

Keywords: Length of stay · Comorbidities · Multiple regression · Femur fracture

1 Introduction

The fracture of the femur is typically associated with the elderly, in particular women, who have greater bone fragility due mainly to osteoporosis and are therefore more likely to have a break. In 2002, over 86,000 hip fractures were recorded in Italy in patients over the age of 45, with a progression of 9% compared to 1999. 77% were female and 80% were over 75 years old [1]. The fracture in the neck of the femur in people over 65 years old is to be considered a very serious event, given that scientific studies attest that a person's survival decreases drastically after such a trauma and that

T. Jarm et al. (Eds.): EMBEC 2020, IFMBE Proceedings 80, pp. 840–847, 2021.
https://doi.org/10.1007/978-3-030-64610-3_94

the mortality rate per year is around 12–37%. Only 50% of patients regain the mobility and independence they enjoyed 12 months before the fracture. In Europe, the economic burden is estimated to be over € 4 bn due to the occurrence of about half a million of new cases per year. The society cannot neglect social costs: orthopedic visits, physiotherapy and medical treatment make the costs rise in the year after the fracture [2, 3]. Recent studies suggest that in Italy the general costs (considering hospitalization, rehabilitation, disability pensions and indirect costs) of fractures of the neck of the femur, in patients over 65, amount to more than € 1,000 m per year [4, 5]. The number of hip fractures worldwide is expected to increase from 1.7 million in 1990 to 6.3 million in 2050 due to an aging population; therefore, the associated total cost will also increase. The cost-effectiveness ratio varies based on the treatment and its effectiveness, but it also depends on the patient's compliance, age, start of treatment and the risk of fracture assigned. Greater cost effectiveness occurs when treatments are most effective and when they are directed to patients with the highest risk of fractures [6].

Healthcare has undergone substantial economic cuts in recent years which in many cases has led to the reduction of available beds. One way to quantify the optimal use of these is by measuring the length of stay (hereinafter LOS). The average length of stay in the orthopedic department is generally greater than 10 days [7] and is strongly correlated to comorbidities. In fact, only 4.9% of patients presented without comorbidities. Comorbidities significantly affect the cost of hospitalization and length of stay following hip fracture in older adults, including by controlling the other variables. Hypertension, deficiency anemia and fluid and electrolyte disturbances are the most common comorbidities [8]. For example, patients who have to undergo particular cardiac tests before surgery [9] or who have an increase in the American Society of Anaesthesiologists (ASA) classification [10] produce an increase in the average LOS. Costs and LOS are generally lower for patients admitted through a 24-hour emergency room, who underwent surgery on the day of admission and were discharged at home [11]. Therefore, to avoid the increase in LOS and unnecessary complications for the patient, it is useful to intervene early with surgery. Several studies have shown the effectiveness of early intervention [12–14]. In particular, the Italian guidelines [15] require that fractures be treated no later than 48 h. To ensure this, various techniques have been applied such as Lean Six Sigma to change the approach to treatment [16–21]. The "San Giovanni di Dio and Ruggi d'Aragona" university hospital in Salerno with the "Femur: zero wait" project aims to revolutionize the overall LOS, applying both a reduction in pre-intervention and post-intervention times, opting, in the second case, for an advance mobilization already on the first post-operative day to accelerate functional recovery and increase the probability of discharge directly at home. In particular, to reduce the pre-intervention times, a new Diagnostic and Care Pathways (DTAP) has been implemented, based on the DMAIC (Define, Measure, Analyze, Improve, Control) cycle and on the application of the principles of Lean Six Sigma. Here, starting from the data collected before and after the implementation of the DTAP "San Giovanni di Dio and Ruggi d'Aragona" university hospital, we build and propose a modeling approach to predict the LOS for patients undergoing femur fracture surgery. The two obtained prediction models (before and after DTAP) will be compared and their potential as a tool to optimize hospital management is discussed.

2 Methods

The study was conducted at the Complex Operative Unit (C.O.U.) of Orthopedic and Traumatology at the "San Giovanni di Dio e Ruggi d'Aragona" University Hospital. The "Femur: zero wait" project was born in 2016. Two different groups of patients operated on due to a fracture to the femur were studied during 1 year before (2015) and 1 year after (2017) the adoption of the new DTAP. The first sample is made up of 547 patients while the second was made up of 562 patients.

In order to construct a model capable of predicting LOS in patients with femoral neck fracture, multiple linear regression (MLR) was used. Multiple linear regression models describe how a single response variable Y depends linearly on a number of predictor variables. In particular, in this work, two models were created: the first using data before the implementation of DTAP and the second using data after the implementation of DTAP.

2.1 Data Collection and Analysis

Data were collected both from the digital information system (QUANI SDO) of the hospital. For each patient included in the study, the following anamnestic, demographic and clinical variables were collected:

- gender (male/female);
- age;
- presence of complications, like cardiovascular diseases or diabetes, (yes/no);
- date of admission;
- date of surgery; and
- date of discharge.

The criteria of inclusion were patients over 65 years with femur fracture as primary or secondary discharges diagnosis. The exclusion criteria, instead, were related to patients with polytrauma and cancer in the primary or secondary diagnosis.

The MLR was performed using IBM SPSS Statistics 20 software.

2.2 Multiple Linear Regression

Multiple linear regression is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. In order to be able to use it, however, the following assumptions must be respected:

- The relationship between the independent and dependent variable is linear.
- There is no multicollinearity in the data.
- The values of the residuals are independent.
- The variance of the residuals is constant.
- The values of the residuals are normally distributed.
- There are no influential cases biasing the model.

In this case the analysis carried out with IBM SPSS Statistic showed that the assumptions are satisfied and MLR was implemented considering the LOS as dependent variable and 4 independent variables: gender, age, presence of complication and pre-operative LOS. The equation obtained for both models is the following:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

where y represents the LOS, x_i the considered variables, β_0 the intercept, β_i the regression coefficients. These models thus allow to predict the duration of a patient's LOS knowing some of his characteristics.

3 Results

The Durbin-Watson test, whose acceptable range is between 1.5 and 2.5, is 1.734 for the model pre-DTPA and 1.843 for the model post-DTPA, confirming the independence of the residuals.

As far as the collinearity, Tolerance and Variance Inflaction Factors (VIF) have been evaluated and both of them show acceptable values (Tolerance > 0.2 and VIF < 10), i.e. no collinearity is detected, as showed in Table 1.

Table 1. Collinearity diagnostics

	Model pre-DTAP		Model post-DTAP	
	Tolerance	VIF	Tolerance	VIF
Gender	0.962	1.040	0.962	1.040
Age	0.959	1.043	0.936	1.068
Presence of complications	0.984	1.016	0.970	1.031
Pre-operative LOS	0.986	1.014	0.989	1.011

As far as the linearity, the strongest linear relationship is observed between pre-operative LOS variables and LOS, while slight linearity is present for the other variables. Absence of potential outliers has been verified by checking the adimensional parameter, the Cook's distance, for each samples, ensuring values lower than the recommended threshold equal to 1.

After the verification of the assumption, in order to assess the goodness of the two models, the coefficient of determination (R^2) and the standard error of the estimate were considered. The Table 2 shows the values for each of the models.

Table 2. Evaluation metrics for the regression analysis

	Model pre-DTAP	Model post-DTAP
R^2	0.63	0.50
Std. error of the estimate	3.12	5.08

The plot of the standardized residuals vs the standardized predicted values for both models are also reported in the following Fig. 1 and Fig. 2.

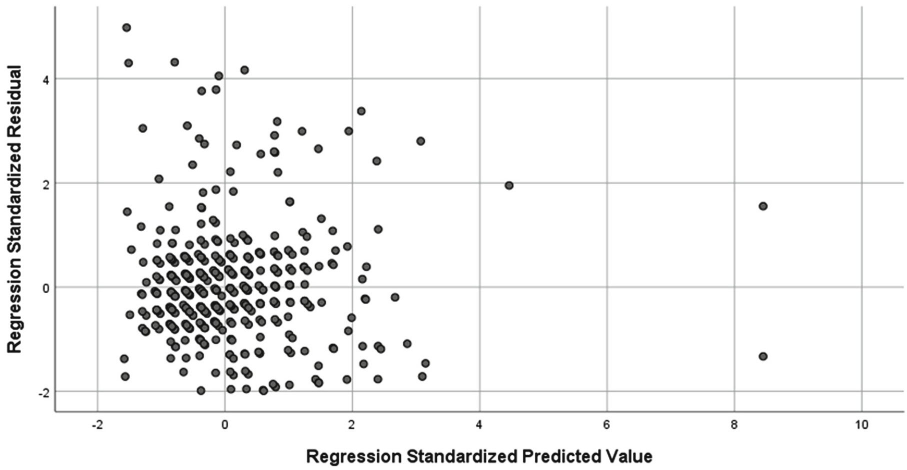

Fig. 1. Standardized residuals vs the standardized predicted values for the pre-DTPA regression model.

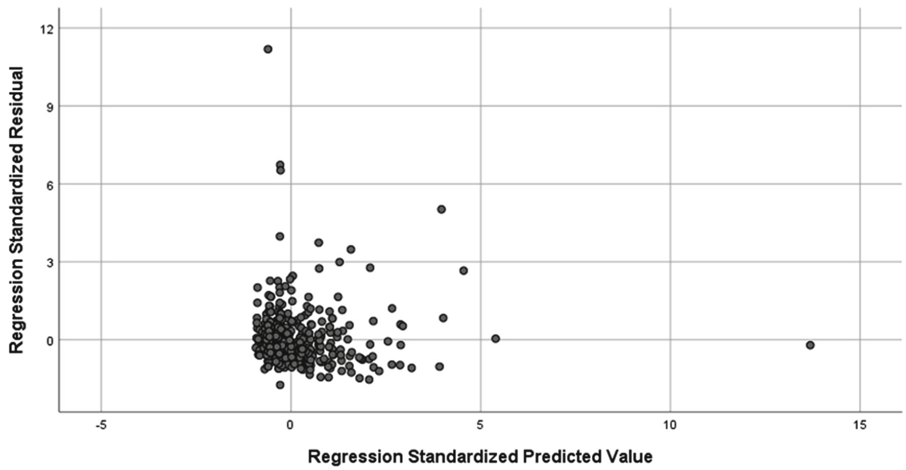

Fig. 2. Standardized residuals vs the standardized predicted values for the post-DTPA regression model.

Despite no significant heteroschedasticity is detected from Fig. 1 and 2, i.e. the variance of the residuals is almost constant, a slight deviation from normality is present for both models, which was verified looking at the cumulative probability plots, here not showed for the sake of brevity.

The pre-DTAP model has a higher R^2 and a lower error standard than the post-DTAP model (Table 2). For this reason it is considered more accurate. In any case, the two datasets are very different from each other because after the implementation of DTAP the pre-operative LOS decreased considerably as well as complications and LOS. However, both models are representative of more than a half of the cases ($R^2 > 0.5$) and therefore they could give a rough but still useful and indicative estimate of the LOS for the considered patients.

The regression coefficients β_i obtained for the two models are shown in Table 3.

Table 3. Regression coefficients

Variables	Regression coefficients (pre-DTAP model)	Regression coefficient (post-DTAP model)
Intercept	6.45	6.217
Gender	−0.20	−0.24
Age	0.005	0.03
Presence of complications	0.196	−0.14
Pre-operative LOS	0.94	1.37

As shown in Table 3, pre-operative LOS is the variable with the highest coefficient for both models and therefore the one that most affects the LOS.

The two models could be improved considering also the other clinical features of the patient. This would give a more complete overview of the clinical situation and enable a more accurate prediction of LOS.

4 Discussion and Conclusion

In this work, a multiple regression model was used to predict the LOS of patients who present in the hospital with a fracture of the femur. The implementation of the new DTAP, based on the Lean Six Sigma logic, has led to a more prompt response and a consequent reduction in LOS. LOS are widely used to evaluate the use of health resources, the costs and severity of the disease [22]. Being able to predict the average length of stay is increasingly important for resource planning and to achieve reference performance levels in terms of profitability, patient care and process efficiency. Providing the hospital administration with an early and accurate forecast is therefore important for economic and organizational reasons [23]. For example, predicting the date of entry and discharge may be useful for planning elective hospitalizations, thus obtaining a less variance in occupancy of the bed [22], for pre-determining specialists for patients with multiple diagnoses [24], for allocate resources in order to guarantee both assistance and teaching [25], a fundamental aspect in a university hospital, and to allow families to better plan the post-hospitalization phase of elderly patients, most affected by this type of fractures [24]. The proposed model, despite displaying a moderate R^2, can be helpful in the determining an estimate of the LOS for patients undergoing femur fracture surgery, thus supporting the decision making process and the management of hospital resources in advance like number of available beds, healthcare staff and operating rooms. In addition, the comparison of between the two models can be used as an indicator to assess the efficiency of the implemented DTAP.

Future developments of this work may involve the implementation of other types of models. In particular the implementation of a non-linear model, such as a neural network, could be very interesting and provide more accurate results. In this way a comparison between multiple linear regression and a non-linear model would be possible. This comparison would then make it possible to determine which model can predict LOS more accurately, providing clinicians a valuable decision-making tool.

Conflict of Interest Statement. The authors have no conflict of interest to declare.

References

1. Rossini, M., Piscitelli, P., Fitto, F., Camboa, P., Angeli, A., Guida, G., Adami, S.: Incidence and socioeconomic burden of hip fractures in Italy. Reumatismo **57**, 97–102 (2005). https://doi.org/10.4081/reumatismo.2005.97
2. Centobelli, P., Cerchione, R., Esposito, E., Raffa, M.: The evolution of engineering management. Education **32**, 1813–1822 (2016)
3. Cerchione, R., Centobelli, P., Esposito, E., Raffa, M.: What is the Engineering Management? Exploring the Emerging Knowledge and Skills for Engineers. https://www.ingentaconnect.com/content/asp/asl/2016/00000022/f0020005/art00104;jsessionid=24wjuun7a1r9r.x-ic-live-01
4. de Mast, J., Does, R.J.M.M., de Koning, H.: Lean Six Sigma for Service and Healthcare. Alphen aan den RijnBeaumont Quality Publications (2006)
5. Van Den Heuvel, J., Does, R.J.M.M., De Koning, H.: Lean Six Sigma in a hospital. Int. J. Six Sigma Compet. Adv. **2**, 377–388 (2006). https://doi.org/10.1504/IJSSCA.2006.011566
6. Johnell, O.: The socioeconomic burden of fractures: today and in the 21st century. Am. J. Med. **103**, S20–S26 (1997). https://doi.org/10.1016/S0002-9343(97)90023-1
7. Torre, M.: Progretto per l´istituzione del Registro nazionale degli interventi di protesi di anca. Istituto Superiore di Sanità (2005)
8. Nikkel, L.E., Fox, E.J., Black, K.P., Davis, C., Andersen, L.B., Hollenbeak, C.S.: Impact of comorbidities on hospitalization costs following hip fracture. J. Bone Joint Surg. Am. (2012). https://doi.org/10.2106/JBJS.J.01077
9. Ricci, W.M., Brandt, A., McAndrew, C., Gardner, M.J.: Factors affecting delay to surgery and length of stay for patients with hip fracture. J. Orthop. Trauma **29**, e109–e114 (2015). https://doi.org/10.1097/BOT.0000000000000221
10. Garcia, A.E., Bonnaig, J.V., Yoneda, Z.T., Richards, J.E., Ehrenfeld, J.M., Obremskey, W. T., Jahangir, A.A., Sethi, M.K.: Patient variables which may predict length of stay and hospital costs in elderly patients with hip fracture. J. Orthop. Trauma **26**, 620–623 (2012). https://doi.org/10.1097/BOT.0b013e3182695416
11. Castelli, A., Daidone, S., Jacobs, R., Kasteridis, P., Street, A.D.: The determinants of costs and length of stay for hip fracture patients. PLoS ONE **10**, e0133545 (2015). https://doi.org/10.1371/journal.pone.0133545

12. Carretta, E., Bochicchio, V., Rucci, P., Fabbri, G., Laus, M., Fantini, M.P.: Hip fracture: effectiveness of early surgery to prevent 30-day mortality. Int. Orthop. **35**, 419–424 (2011). https://doi.org/10.1007/s00264-010-1004-x
13. Moja, L., Piatti, A., Pecoraro, V., Ricci, C., Virgili, G., Salanti, G., Germagnoli, L., Liberati, A., Banfi, G.: Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. a meta-analysis and meta-regression of over 190,000 patients. PLoS One **7**, e46175 (2012). https://doi.org/10.1371/journal.pone.0046175
14. Nyholm, A.M., Gromov, K., Palm, H., Brix, M., Kallemose, T., Troelsen, A.: Danish fracture database collaborators: time to surgery is associated with thirty-day and ninety-day mortality after proximal femoral fracture: a retrospective observational study on prospectively collected data from the danish fracture database collaborators. J. Bone Joint Surg. Am. **97**, 1333–1339 (2015). https://doi.org/10.2106/JBJS.O.00029
15. Decree of the Italian Ministry of Health (DM 12 Marzo 2019). 'Nuovo sistema di garanzia per il monitoraggio dell'assistenza sanitaria' (2019)
16. Improta, G., Ricciardi, C., Borrelli, A., D'alessandro, A., Verdoliva, C., Cesarelli, M.: The application of six sigma to reduce the pre-operative length of hospital stay at the hospital Antonio Cardarelli. Int. J. Lean Six Sigma (2019). https://doi.org/10.1108/IJLSS-02-2019-0014
17. Ricciardi, C., Fiorillo, A., Valente, A.S., Borrelli, A., Verdoliva, C., Triassi, M., Improta, G.: Lean Six Sigma approach to reduce LOS through a diagnostic-therapeutic-assistance path at A.O.R.N. A. Cardarelli. TQM J. **31**, 657–672 (2019). https://doi.org/10.1108/TQM-02-2019-0065
18. Improta, G., Balato, G., Romano, M., Ponsiglione, A.M., Raiola, E., Russo, M.A., Cuccaro, P., Santillo, L.C., Cesarelli, M.: Improving performances of the knee replacement surgery process by applying DMAIC principles. J. Eval. Clin. Pract. **23**, 1401–1407 (2017). https://doi.org/10.1111/jep.12810
19. Improta, G., Guizzi, G., Ricciardi, C., Giordano, V., Ponsiglione, A.M., Converso, G., Triassi, M.: Agile six sigma in healthcare: case study at santobono pediatric hospital. Int. J. Environ. Res. Public. Health **17** (2020). https://doi.org/10.3390/ijerph17031052
20. Ricciardi, C., Balato, G., Romano, M., Santalucia, I., Cesarelli, M., Improta, G.: Fast track surgery for knee replacement surgery: a lean six sigma approach. TQM J. (2020). https://doi.org/10.1108/TQM-06-2019-0159
21. Ricciardi, C., Sorrentino, A., Improta, G., Abbate, V., Latessa, I., Perrone, A., Triassi, M., Dell'aversana Orabona, G.: A health technology assessment between two pharmacological therapies through Six Sigma: the case study of bone cancer. TQM J. ahead-of-print (2020). https://doi.org/10.1108/TQM-01-2020-0013
22. Hachesu, P.R., Ahmadi, M., Alizadeh, S., Sadoughi, F.: Use of data mining techniques to determine and predict length of stay of cardiac patients. Healthc. Inform. Res. **19**, 121–129 (2013). https://doi.org/10.4258/hir.2013.19.2.121
23. Tanuja, S., Acharya, D., Shailesh, K.: Comparison of different data mining techniques to predict hospital length of stay. Presented at the (2011)
24. Morton, A., Marzban, E., Giannoulis, G., Patel, A., Aparasu, R., Kakadiaris, I.A.: A comparison of supervised machine learning techniques for predicting short-term in-hospital length of stay among diabetic patients. In: 2014 13th International Conference on Machine Learning and Applications, pp. 428–431 (2014)
25. Omachonu, V.K., Suthummanon, S., Akcin, M., Asfour, S.: Predicting length of stay for Medicare patients at a teaching hospital. Health Serv. Manage. Res. **17**, 1–12 (2004). https://doi.org/10.1258/095148404322772688