ISSN: 2321-8819 (Online) 2348-7186 (Print) Impact Factor: 1.498 Vol. 7, Issue 8, August, 2019

Analysing the Time of Bed Availability in Intensive Care Unit of Accident and Orthopaedic Department Using Survival Analysis.

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Abstract

Purpose

Optimizing the available resources in a hospital helps to improve the capacity utilization in the respective divisions. Predicting the length of stay (LoS) of patients admitted to Intensive Care Unit (ICU) gives a clear vision to the physicians and the administrative level to improve the productivity and to plan its staffing policy.

Method

The study was carried out for all the patients admitted to the ICU in Accident and Orthopaedic Service to estimate their LoS in ICU using survival analysis. Data obtained were identified as censored or non-censored data and were categorized based on their gender, age and the type of injury. Kaplan-Meier estimates were used to predict the LoS of patients based on the above categories. Finally, the best fitted survival model, logistic model was used to identify the significance of gender, age and the type of injury of the patients on their LoS.

Results

The probability of discharging a female patient within less number of days was higher than that of male patients. Senior adults recorded the highest LoS. When patients were categorized based on the type of injury, highest LoS was recorded by the patients with facial injuries. According to the log-rank test only the levels of age (*p value* = 0.04) and injuries (*p-value* = 0.04) show a statistical difference between the respective variable levels. Gender does not show a significance relation with the LoS.

Conclusion

The patients' age and the type of injury were significantly related to LoS of ICU patients.

Keywords: Survival Analysis, Bed Occupancy, Intensive Care Unit, Length of Stay

Introduction

The study was conducted in the Accident and Orthopaedic Service unit in a leading hospital in Sri Lanka. The hospital has been expanded with many healthcare services over the years. The Accident and Orthopaedic Service (AOS) plays a vital role in providing medicine treatments and care for patients with emergency injuries and illnesses. The Intensive Care Unit of AOS consists of 6 beds with ventilators.

AOS provides treatments for a broad spectrum of injuries. Some of the patients may require specialized care and monitoring and some may be on the verge of losing their battle to survive. The Intensive Care Units (ICUs) are specialist hospital wards which cater to those who need specialized care and monitoring and those with life-threatening injuries or illnesses (Knaus,et al.,1994). Primary responsibility of the ICU is to relieve and prevent situations like risk of survival with unacceptable quality of life, physical and psychological suffering, and loss of dignity as much as possible (Suter,et al.,1994)

Lack of bed availability in ICU is one of the notable problems in AOS which leads to the ICU crowdedness (McConnell,et al.,2005).When the service is operating in full capacity, a newly arriving patient must wait until the service facility becomes available or leave without the service. Introducing new facilities including physical and human resources would help to overcome this problem. But due to constraints in space and time and due to high cost, expansion of ICU is not a better solution to overcome this problem. Thus, optimizing the available resources would help the administrative staff to provide high quality service to the patients.

Predicting the number of free beds in an ICU is a difficult task as most of the patients visit AOS

without any prior appointment. Thus, focusing on the factors that drive the Length of Stay (LoS) of ICU patients help to improve the productivity, capacity utilization in ICU while ensuring that resources are available to meet the healthcare needs of the patients admitted to ICU.

Queuing theory has been used in several studies to model the bed occupancy in hospitals. The queuing models fitted were used to predict the arrival rates of patients with similar type of illnesses (Green,2003; Knaus, et al.,1994; Mcmanus, et al.2004).Queuing theory cannot be applied to the current study as the study was conducted on an ICU in AOS unit as the patients admitted to the ICU are with different types of injuries. Hence, the current paper used a survival model to model the bed availability of ICU patients. Prior studies have used survival analysis to examine the survival rates of elderly persons in an ICU (Bonfada & Lima, 2017). But no previous research has focused on all the patients admitted to ICU using survival analysis.

Methodology

Records of the patients who were admitted to the ICU between 01st of January and 26th of December 2018 were extracted from the Admission book maintained by the ICU. The sample size was 221.These data cover clinical details of individual patients which include date of admission, date of transfer, age and injury type and details of patients who were transferred from ICU and those who died in their stay at ICU.

Descriptive analysis was performed using SPSS software and the survival analysis using R software version 3.5.2. Log-rank test was used to observe the significance difference between the estimated survival curves of patients by gender, age and type of injury.

Patients who were admitted to the ICU of AOS were classified according to the classification criteria used for Injury Severity Score (ISS) and the patients with many injuries were considered as one category. The ISS is an internationally recognised scoring system which correlates with mortality, morbidity and other measures of severity (Goris,1983). According to ISS, the body regions are classified as follows: Head or neck injuries, Facial injuries, Chest injuries, Abdominal or pelvic contents injuries, Extremities or pelvic girdle injuries, External and other trauma injuries. Patients admitted to ICU were also classified based on their age as follows: Paediatrics (0 to 12 years), Adolescence (13-18 years), Young Adults (19- 29 years), Adults (30- 50 years) and Senior Adults (Above 50 years) (McConnell,et al.,2005).

The LoS was taken as the outcome variable of interest for the survival analysis which is the period between date of admission and date of transfer. Unlike the other analysing processors, survival analysis consists of incomplete data termed as censoring. Censoring variable(C) is defined as follows, $C = 1$ if the patient was transferred to a ward, $C = 0$ if patient died or transferred to another hospital or to another ICU in the hospital. The Kaplan Meier (KM) method is widely used to estimate the survival probabilities. For the comparison of survival curves log rank test was used. The log–rank test is a large-sample chi-square test that uses as its test criterion a statistic that provides an overall comparison of the KM curves being compared. A parametric survival model is one in which survival time (the outcome) is assumed to follow a known distribution. Weibull, Exponential, Logistic, Gauss, and few other models were considered in this study (David & Kleinbaum, 2005). Among them, the best model for the study was selected based on the best AIC criterion i.e. the model with the least AIC value is considered as the best model.

Results and Discussion

Descriptive Analysis

For Descriptive analysis, summary measures were obtained for all the qualitative and quantitative variables with diagrams where needed. Survival analysis consists of techniques that can be used for analysing time to event data also known as lifetime data or failure time data.

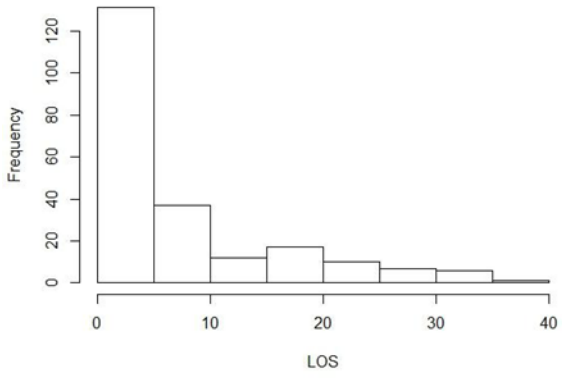


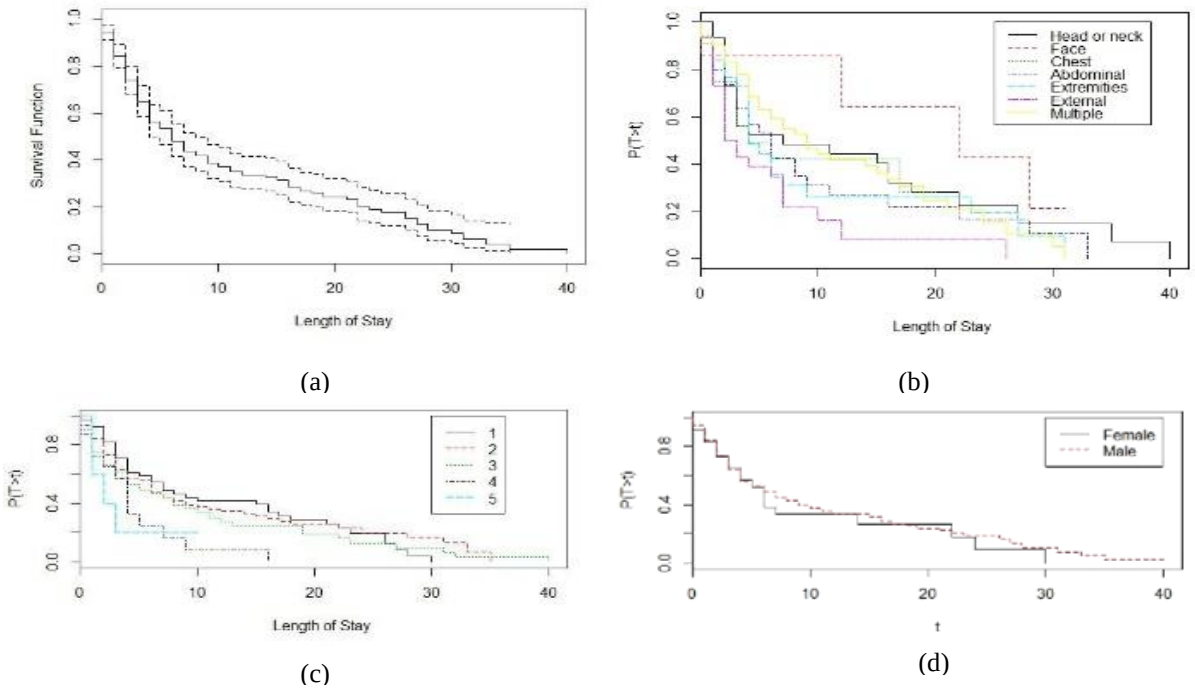
Fig.1 Histogram of length of stay of ICU patients

Length of stay of patients can be considered as the indicator of the performance of the hospital. The LoS of ICU patients are positively skewed (Figure1). The maximum number of days a patient stays in the ICU was recorded as 40 days. Since the data are positively skewed, the median length of stay is considered for the study as the sample mean exceeds the median (Lee, et al., 2009).

Results of Survival Analysis

Figure 2(a) shows the survival curve, the proportion of individuals who have survived until a given period. The curve drops to a lower value at each record of the LoS of ICU patients as the study period is limited and the number at risk drops with each unique event time. The KM survival probability estimates that there is a 0.5 probability to discharge a patient from the ICU within 6 days (95% CI: 4,8) i.e. there is a 50% of chance to discharge a patient within 6 days.

According to the plot of KM estimates of gender (Figure 2(d)), there seems to be no difference in the probability of discharging patients according to gender in the early stage but the probability of discharging a female patient within less number of days is higher than that of male patients. Almost all the female patients have been discharged within 30 days and the maximum length of stay is recorded by male patients even though the probability of discharging male patients on the date of admission is slightly higher than that of female patients.



(a) (b) (c) (d)

1-Paediactrics, 2-Adolesents, 3-Young adults, 4-Adults, 5-Senior adults

Fig.2 (a) Plot of Kaplan Meier estimate with 95% confidence interval (b) Plot of Kaplan Meier estimates for age (c) Plot of Kaplan Meier estimates for injury type (d) Plot of Kaplan Meier estimates for gender

Table 1: Median LOS of patients based on age and injury type

Variable	Variable levels	Median LOS
Age	Paediatrics	2
	Adolescence	3
	Young Adults	5
	Adults	6
	Senior Adults	7
Injury	Head or Neck	7
	Facial	12
	Chest	4
	Abdominal	5
	Extremities	4
	External	2
	Multiple	8

The Kaplan Meier survival probability estimates that there is a 0.5 probability to discharge a paediatric from the ICU within 2 days, an adolescent within 3 days, a young adult within 5 days and adults within 6 days and a senior adult within 7 days. There seems to be no difference in the probability of discharging adult patients with comparison to senior adult patients (Figure 2(c)). The LoS of young adult patients seems to be higher than the other patients. The shape of the survival curve is preserved as the number of adults, young adult and senior adult patients are high in the sample. Since the number of paediatrics in the sample is less, the curve drops with large steps and almost all the paediatrics have been discharged within 10 days. There is a 0.95 probability that paediatrics get discharged within 3 days and adolescents within 9 days, young adults within 31 days, adults within 33 days and senior adults within 27 days.

According to the plot of Kaplan Meier estimates of Injury, there is a 0.5 probability to discharge a patient with a head injury from the ICU within 7 days, a patient with a face injury within 12 days, patients with a chest injury and patients with injuries in the category extremities within 4 days, a patient with abdominal injury within 5 days, ones with external injuries within 2 days and the patients with multiple injury within 8 days. There is 0.95 probability to discharge a patient with a head injury within 35 days, a patient with abdominal injury within 28 days, patients belonging to the extremities category within 23 days, ones with external injuries within 12 days and the patients with multiple injury within 30 days. Highest LOS is recorded by patients with head injuries (Figure 2(b)).

Comparison of survival distributions

H_0: There is no statistical difference between the survival probabilities of variable levels

H_1: There is a statistical difference between the survival probabilities of variable levels

According to the log-rank test, the difference of the survival function of length of stay according to gender, is not significant at 5% level of confidence. Hence, we do not have enough evidence to reject H_0 at 5% level of significance. Thus, there is no statistical difference between the survival probabilities of males and females. Levels of age and injuries of patients are significant at 5% level of significance. Hence, H_0 can be rejected at 5% level of significance. This implies that there is a statistical difference between levels of age and injuries.

Parametric Models to Predict the LoS

To choose the best fitted model, Weibull, Exponential, Logistic, Gaussian, Log-normal and Log-logistic and the Cox-proportional models were considered. Considering the parametric models, the *p value* =0.12 for the Gaussian model and the *p value* =0.05 for the logistic model. Therefore, only the logistic model is significant at 10% level of significance. Therefore, it was concluded that the Logistic Model is the suitable Parametric model to give conclusions about the LoS of patients admitted to the ICU. The following results can be drawn from the logistic model.

Table 2: Logistic model

Factors	Reference level	Value	Standard Deviation	*p-value*
(Intercept)		10.2840	2.5437	5.3e-05
(Gender)Male	Female	-0.1633	1.7740	0.927
(Age) Adolescent	Paediatrics	-0.4138	1.5999	0.796
Young adults	Paediatrics	-0.6920	1.8262	0.705
Adults	Paediatrics	2.6855	2.9018	0.355
Senior adults	Paediatrics	4.9131	4.4236	0.267
(Injury)Facial Injury	Head or Neck	11.2361	4.9290	0.023
Chest Injury	Head or Neck	-1.4319	2.8286	0.613
Abdominal Injury	Head or Neck	-2.4218	2.3898	0.311
Extremities	Head or Neck	-2.8450	2.4117	0.238
External Injury	Head or Neck	-5.2937	2.3407	0.024
Multiple Injury	Head or Neck	0.6911	2.2200	0.756
Log(scale)		1.6277	0.0679	2e-16

There is no significance effect of gender on LoS at 5% level of significance. This result is consistent with results from literature (Barado, et al., 2012). But according to (Mostafa,2002; Reinikainen, 2005) the length of stay of male patients were higher than female patients.

The LoS of Paediatrics, and adolescents are significant when compared to the LoS of seniors adult patients at 5% level of significance. In the study by Singler et al. there is a correlation between patients age and LoS (Singler, et al., 2013).

Except the patients with chest injuries and multiple injuries , the LoS of patients with other injuries are significantly different compared to the LoS patients with head injuries at 5% level of significance.

Comparing the AIC values of the logistic model (1222.987) and the cox-proportional model (1365.338) , the smallest AIC value was recorded in the Logistic model.Therefore, Logistic Model is the best model for this study.

Limitations

The data required for this study had not been computerized. Some of the details of the patients had not been recorded in the book.Hence, the patients with incomplete details were excluded from the study. Length of stay of patients were assumed to be independent of one another and independent of the number of beds occupied. When categorizing the patients based on the injuries, the exact severity of those patients were not considered as they were not recorded.Also, there was no available data about the patients that could not be admitted to ICU due to overcrowdedness. This model should be generalized to the other intensive care units in the different departments in the hospitals or for other hospitals with care as a standard method was not followed to classify the patients based on their age and type of injury and due to non-similar conditions (Barado, et al., 2012)

Conclusion

Patients' age and the type of injury are significantly related to LOS of ICU patients.There is no correlation between the gender and LOS of patients. The length of stay of paediatrics who got admitted to the ICU is less than the length of stay of other patients. Maximum length of stay was recorded by senior adults. With the increment of the age, length of stay of patients also increases. Patients who got admitted to the ICU with an external injury will stay a lesser number of days than the patients with other injuries. Highest length of stay was recorded by patients with facial injuries.

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