MA678 Midterm Project: Modeling Length of Rehabilitation Stay for Spinal Cord Injury Patients

Rose Determan

December 12, 2021

Contents

Abstract

Spinal cord injuries (SCI) are costly and lifelong medical conditions. The first weeks and months after an injury are crucial to recovery, but many variables impact the timeline of patient recovery. Both hospitals and patients can benefit from an accurate prediction of length of stay. In the following analysis, I have modeled the days spent hospitalized in inpatient rehabilitation following an injury using a fixed effect linear model and then a multi-level linear model. Ovarall, although still imperfect, the mixed effect model is more effective and accurate.

Introduction

Spinal cord injuries (SCI) can be an extremely serious condition where the spinal cord is damaged and has a decreased ability to send and receive nerve signals. Symptoms can include paralysis, pain or pressure in head, neck, or back, weakness and/or inability to move any part of the body, and difficulty breathing (Mayo Clinic, 2021). In the United States, in 2021, it is estimated that there are approximately 54 cases of SCI per 1 million (Jain et al., 2015). The spinal cord is divided into neurological segments. For analysis, the cervical and thoracic segments have been selected. Each named segment roughly corresponds to muscle groups and functions, and damage at a higher level likely indicates more serious impairment. For example, if there is an injury at the C4 level, the individual likely will have weak deltoids (in the shoulder region) and reduced strength and sensation everywhere below this region (Young, 2021).

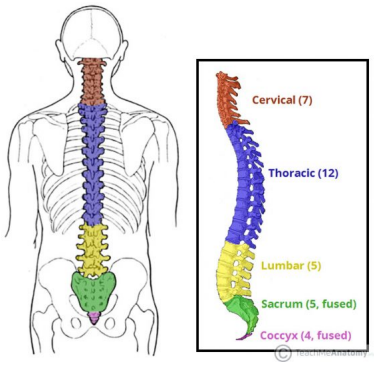

Figure 1: Source: Jones, Olivia. The Vertebral Column, 23 September 2020. https://teachmeanatomy.info/back/bones/vertebral-column/

Since 1973 the National Spinal Cord Injury Model Systems have been collecting data in a database. The database is well managed and extensively documented. The data come from 29 facilities across the United States. The database includes information on 32,159 individuals from 1972 to 2016 and includes a variety of fields which include, for example, injury year, age at injury, sex, use of mechanical ventilation, functional independence scores, ASIA motor index scores, and ASIA sensory scores. This report focus on the modeling the number of days that a patient is hospitalized in inpatient rehabilitation. This is the time after a patient has been treated medically/surgically and before they are discharged from care. This information is relevant to hospitals, so they are able to plan treatment for patients and estimate the number of patients they can care for in a given time. This information is also relevant to patients and their families, so they can also plan the next steps in the patient's recovery.

Variable	Abbreviation	Definition	Notes
Total days inpatient rehab	AHDaSyRb_log	Total length of stay in inpatient acute/subacute rehabilitation unit until discharge, only days for which charges are incurred	log transformed
Days from injury to rehab admission	AI2RhADa_log	Number of days from the date of injury to the first admission to the inpatient rehab unit	log transformed
BMI	ABMI_st	Calculated from provided height and weight. $weight (lb) / [height (in)]^2 x 703$	centered at 0 and scaled by st.dev
Age at injury	AInjAge	Age of patient (years) on the date the SCI occurred	categorical
Functional independence motor score	AFScorRb	Total score of measures including self care, sphincter control, mobility, locomotion, and eating	valid range = 13-91
Use of mechanical ventilation	AUMVAdm_rcc	Any use of mechanical ventilation used to sustain respiration at admission to rehab?	recoded to be binary (1 = yes. 0 = no)
Vertebral injury	AVertInj	Was there a spinal fracture and/or dislocation in addition to the SCI?	binary (1 = yes. 0 = no)
Spinal surgery	ASpinSrg	Was there surgery performed? Includes limited list of relevant surgeries.	binary (1 = yes. 0 = no)
Associated injury	AAsscInj	Was there an additional injury? Includes a limited list of injuries, for example, chest injury, fractures, and amputations	binary (1 = yes. 0 = no)
Neurologic level of injury	ANurLvlR_rcc	The highest point on the spine where normal sensory and motor function can be identified at admission to rehab	Categorical. Selected C01-C08 and T01-T12

Methods

First, I selected relevant variables which are listed in the table. Although the dataset was well organized and documented, I removed missing and unknown values and completed some centering, scaling, and recoding of variables. Any modifications can be found in the `clean_data.R` file, and brief notes are listed in the table. I selected cervical and thoracic injuries, since there are 4582 and 2510 cervical and thoracic injuries in the complete data set and only 607 lumbar injuries and 9 sacral injuries listed. In addition, individuals 0-14y were excluded from the analysis due to a high rate of missing data. After removing the missing data and the excluded variables, the dataset includes 5168 individuals with injuries from 2006 to 2016. Next, I fit a fixed effect model and random effect model to predict log(days hospitalized in inpatient rehab). The random effect model includes a random intercept based on neurologic level of injury and a random slope for the log(days from injury to inpatient rehab admission) which is also based on neurologic level of injury.

```
AHDaSyRb_log ~ AI2RhADa_log + ABMI_st +  AInjAge + AFScorRb + AUMVAdm_rcc + AVertInj+
ASpinSrg+ AAsscInj +  ANurLvlR_rcc
```

```
Random effect: AHDaSyRb_log ~  AI2RhADa_log + ABMI_st +  AInjAge + AFScorRb + AUMVAdm_rcc
+ AVertInj+ ASpinSrg+ AAsscInj + (1 + AI2RhADa_log | ANurLvlR_rcc)
```

I anticipate that the level of injury will impact the "baseline" of days hospitalized. I also anticipate that different levels of injury would also have a varied impact on the influence of log(days) from injury to rehab admit on the log(days) hospitalized in inpatient rehab. The models were evaluated using posterior predictive checks and leave-one-out validation (loo).

Results

Exploratory Data Analysis

The mean log(days) hospitalized in inpatient rehab varies based on level of neurologic injury. I expected high level injuries to have longer hospital stays on average, and this was largely true The average stay was 52 $\pm$ 1 days (95% confidence interval of the mean). Nearly 23% of individuals in the dataset had a C04 level injury and an average rehab stay of 62 $\pm$ 2 days (95% CI), which was also the longest stay of all injury levels. Each selected variable has some relationship with the response variable. Examining the plot of comparisons, a longer time from injury to rehab admit corresponds to a longer stay in rehab, and a higher independence score corresponds to a shorter stay in rehab. Both of these relationships make