



# Prediction modeling and pattern recognition for patient readmission



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## ABSTRACT

Readmission is a major source of cost for healthcare systems. Hospital-specific readmission rates are considered an indicator of hospital performance and generate public interest regarding the health care quality. We aimed to identify those patients who are likely to be readmitted to the hospital. The identified patients can then be considered by health care personnel for application of preventive alternative measures such as: providing intensive post-discharge care, managing the conditions of the most vulnerable in their home, supporting self-care, and integrating health services and information technology systems to avoid unnecessary readmissions. Neural Network, Classification and Regression model and Chi-squared Automatic Interaction Detection models were used for the readmission prediction. All models were able to perform with an overall accuracy above 80%, with the latter two models having the advantage of providing the user with the opportunity of selecting different misclassification costs. We employed C5.0 algorithm to search for recurring pattern in the history or demographics of patients who have been readmitted and explored if a rule of thumb can be derived to predict those at risk of future readmissions. Moreover, the key variables influencing readmission were studied based on a large data set. The most important factors contributing to readmission were determined such as age, sex, number of previous prescriptions and length of previous stays, place of service, and number of previous claims.

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## 1. Introduction

Re-hospitalization is a major issue of concern for the U.S. healthcare system. According to the [American Hospital Association's \(2013\)](#) annual survey of U.S. hospitals, the total number of admissions exceeded 36 million in 2011 and as the numbers from the Agency for Healthcare Research and Quality (AHRQ) show, about one in 10 hospitalizations in 2008 was potentially unnecessary ([AHRQ, 2010](#)). This problem is costly. For example, in 2008, \$12 billion of Medicare spending went towards potentially preventable readmissions according to the Medicare Payment Advisory Commission (MedPAC)'s report to Congress ([Glenn and Hackbarth, 2009](#)). [Carey and Stefos \(2015\)](#) found that, overall, hospitals could expect to save \$2140 for the average 30-day readmission avoided. For heart attack, heart failure, and pneumonia patients, expected readmission cost estimates were \$3432, \$2488, and \$2278, respectively. For high-risk patients, including those with severe illnesses and complications, those expected costs more than doubled.

Hospital-specific readmission rates are considered an indicator of hospital performance and generate public interest regarding the health care quality. Some policy makers are considering either rewarding hospitals with low readmission rates or penalizing those with high rates, and studies have been done to introduce a consensus method of calculating the readmission rate in order to make it a more reliable quality-of-care indicator for comparison and ranking of hospitals ([van Walraven et al., 2012](#)).

Research has been done to determine which factors contribute to early re-hospitalization, mostly limiting the population under study to the elderly, patients with a specific disease or a certain ethnicity ([Marcantonio et al., 1999](#); [Philbin and DiSalvo, 1999](#); [Ottenbacher et al., 2000](#); [Shyu et al., 2002](#); [Reuben et al., 2002](#); [Hamner and Ellison, 2005](#); [Wong et al., 2010](#); [Allaudeen et al., 2011](#); [Dunlay and Gersh, 2013](#); [Engoren et al., 2013](#); [Njagi et al., 2013](#)). Much attention has been given to predicting hospital readmission within a thirty-day time frame after discharge as a binary value ([Marcantonio et al., 1999](#); [Lagoe et al., 2001](#); [Shyu et al., 2002](#); [Wong et al., 2010](#); [van Walraven et al., 2012](#)).

Applying a comprehensive dataset that make generalization more reasonable, we aimed to identify those patients who are likely to be readmitted to the hospital. The identified patients can then be considered by health care personnel for application of preventive alternative measures such as: providing intensive post-discharge care, managing the conditions of the most vulnerable in their home,

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supporting self-care, and integrating health services and information technology systems to avoid unnecessary readmissions. In this research, we investigated the following research questions:

- What are the key variables influencing readmission?
- What is the recurring pattern in the history or demographics of patients who have been readmitted?
- What rule of thumb can be derived from these patterns to predict those at risk of future unnecessary readmissions?

We employed secondary data from a local hospital that recorded medical data over three years (in contrast with the extant

literature, which is usually based on a short period of time) for an exceptionally comprehensive population of more than 113,000 patients, inclusive of a range of ages and health conditions. We developed predication models to identify patients who are more likely to be readmitted and compared the results.

The remainder of this paper is organized as follows. A detailed background of the research already carried out on risk-predicting models for hospital readmissions is provided in [Section 2](#). [Section 3](#) explains the methodology and [Section 4](#) describes the data and explains the process of data preparation. [Section 5](#) elucidates the modeling techniques. A discussion of the results is presented in

**Table 1**  
Risk factors considered as the most important contributors to readmission in previous studies.

Factors	Literature									Total number of factors
	Boult et al. (1993)	Marcantonio et al. (1999)	Lyon et al. (2007)	Reuben et al. (2002)	Billings et al. (2006)	Bottle et al. (2006)	Donnan et al. (2008)	van Walraven et al. (2012)	Donzé et al. (2013)	
Age	X	X			X	X	X			5
Ethnicity					X	X				2
Sex	X			X	X	X	X			5
Availability of an informal caregiver	X									1
Local admission rate						X				1
Not working				X						1
Area-level socio-economic data						X				1
High social deprivation							X			1
Sodium level at discharge									X	1
Hemoglobin at discharge									X	1
Discharge from an oncology service									X	1
Lack of documented patient or family education		X								1
Depression		X								1
Religious participation				X						1
Low iron level				X						1
Low serum albumin				X						1
Taking loop diuretics				X						1
Number of respiratory medications							X			1
Previously prescribed analgesics, antibacterials, nitrates & diuretics							X			1
Procedure									X	1
Admission for an ambulatory Care sensitive condition						X				1
Acuity of admission								X		1
Source of admission						X				1
Type of admission									X	1
Clinical condition					X					1
Leg ulcers			X							1
Heart problem			X							1
Diabetes	X			X						2
More than six doctor visits	X									1
ER admission during the last year/last 3 years/ last 6 months			X			X		X		3
Hospital admission during the last year/last 2 years/ 30 days				X	X		X		X	4
Having ever had coronary artery disease	X									1
Length of stay							X	X	X	3
Comorbidity		X				X		X		3
Unable to walk 0.5 mile				X						1
Needing help bathing				X						1
Ability to go out of the house without help			X							1
Self-rated general health	X		X	X						3
Memory loss			X							1

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