Score Based Anticipative Transfer Requests in the Intensive Care Units

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1 Introduction

An intensive care unit (ICU) is a specialized hospital department that provides temporary support to critically ill patients. A significant portion of hospital operating costs (20% in the U.S.) is due to the ICU. Therefore, the efficient operation and management of ICUs is critical to providing high quality of care while managing costs. In this paper, we show that the effective use of clinical markers combined with improved operations can significantly decrease transfer delays without increasing capacity. Better predictions of performance measures are essential for optimal management of units. In that regard, we construct a new Transfer Score to estimate readmission and death probabilities upon transfer to a lower level of care unit. On our dataset, our score provides better estimations than all other models in the literature. The ability to make accurate predictions of performance measures enhances the ability to manage ICUs. We illustrate that an anticipative transfer request policy significantly increases the performance of the whole system. Transfer delays can be reduced by giving early transfer requests in which a downstream bed is requested before the patient is medically ready to be transferred. Furthermore, we show that the beds can be reallocated among units under the policy.

2 ICU Transfer Score

We employ a database from a major medical institution, which contains both medical and bed flow information of 17,203 patients from 2003 to 2008. We build a logistic regression model to estimate readmission and death probabilities upon transfer to a lower level of care unit. Our model provides an 80% Area under Curve (AUC), compared to the best known AUC in the literature, 74%. We examine the significance of many clinical factors, as well as operational
factors like utilization, on the probability of readmission and death. We show that the dynamic tracking of clinical markers provides a significant explanation power. Not surprisingly, we show that the risk of readmission increases when the ICU is more utilized or the patient is already a readmitted patient. Finally, we present a new Transfer Score based on our model. We also analyze the probabilistic evolution of this new transfer score. We compare different stochastic processes such as Discrete Time Markov Chain (DTMC) and time series models in order to model the evolution of the score.

3 Score Based Early Transfer

Reducing the transfer delays in order to reduce ICU congestion is critical. Generally, when a patient is medically ready to be transferred to a lower level of unit, a transfer request is made and the patient is transferred after a significant delay (approximately 5 hours and even up to 24 hours). This delay is caused by many factors such as bed availability, personnel availability, cleaning the target beds etc. One should note that the patient stays in the ICU while transfer operations are conducted, so a new patient cannot be admitted to the ICU during this time. In other words, transfer delay is attributed to patient LOS in the intensive care where he uses the expensive ICU bed instead of a relatively lower cost downstream bed. A policy that reduces the medically unnecessary LOS in the ICU will yield a more effective system. We consider a system where doctors monitor the status (transfer score) of the patients and have real time estimates on the evolution of the score. We assume that transfer requests are given before the patients are medically ready to be transferred and necessary preparations in the down-stream start after the request, so that patients can be immediately transferred to the downstream unit whenever the patient becomes medically ready. We note that patients cannot be transferred unless they are medically dischargeable or the downstream bed is not available. This differentiates our approach
from early discharge policies, since we guarantee a certain quality of care. On the other hand, the stochastic nature of the patient’s health status might yield unnecessary bed requests from the downstream unit and increase the congestion in the downstream unit due to early allocations. To this end, we need to determine the optimal timing of the transfer request.

**Dynamic Programming Model:** We present an infinite horizon discrete time Markov Decision Process (MDP) model for the transfer request problem. The state is defined as the transfer scores of all patients. The health status of each patient evolves according to a DTMC independently. The physician monitors status of each patient and determines the number of requests at each discharge round. We penalize the time that a patient stays in the ICU although he/she is dischargeable, as well as the time that a downstream bed is allocated, but not utilized. The exact solution of the model is not tractable for medium size ICUs (10-25 beds), hence we provide approximation techniques based on state sampling and simulations. In addition, we analyze single patient version of the problem in which we show that under certain conditions there exists a threshold where it is optimal to make a transfer request. We utilize the solution of the single patient problem in our approximations to obtain bounds on the original problem. To illustrate the benefits of the early transfer request policy we conduct a numerical study based on a large data set, and compare our results with the current practice. We show that the proposed policy increases the throughput of the system without decreasing the quality of care, and increasing the capacity. We make a sensitivity analysis on the penalty costs, which provides managerial insights for different allocations of beds between ICU and downstream units.