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MODELING STAFFING NEEDS IN A NEONATAL INTENSIVE CARE UNIT

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ABSTRACT

Patient safety in a neonatal intensive care unit (NICU) is critically dependent on appropriate staffing. We used SAS® Simulation Studio to create a discrete-event simulation model of a specific NICU that can be used to predict the number of nurses needed per shift. The model incorporates the complexities inherent in determining staffing needs, including variations in patient acuity, referral patterns, and length of stay. The general basis of the model represents a method that can be applied to any NICU, thereby providing clinicians and administrators with a tool to rigorously and quantitatively support staffing decisions. The use of such a model over time can provide significant benefits in both patient safety and operational efficiency and help optimize the balance between cost and quality of care.

1 INTRODUCTION

The medical director of a neonatal intensive care unit (NICU) faces unimaginable administrative challenges of meeting the critical-care needs of its patients, all of whom are babies ranging from hours-old premature newborns weighing less than a pound to months-old infants weighing 10 times as much as their neighbors. These challenges include assigning the right levels of acuity (a measure of how sick a patient is and thus how many resources are required to provide appropriate care) and finding the right number of nurses to staff the unit's current needs while accounting for the inevitable critical admission or patient who crashes (that is, whose clinical condition suddenly deteriorates). Accurate scheduling of nurses is crucial in optimizing the balance between cost and quality of care. In addition, administrators must plan for their NICU's future, plotting a course for growth and development.

We developed a simulation model using SAS Simulation Studio that uses Duke University Hospital NICU's physical size, structure, and nursing practices as well as de-identified, retrospective patient outcomes data as the initial inputs. Although it remains impossible to account for all variables that affect a hospital unit's day-to-day variations in census (the number of patients in the unit) and acuity, it is possible to develop a valid simulation model that samples from probabilistic distributions based on past experience to simulate days, months, or years of patient admissions and discharges, as well as patient acuity, nursing needs, and transfer capabilities. Furthermore, such a model can be adjusted to predict growth and answer important business questions, including the following: What happens to the NICU if it partners with another hospital and begins accepting 100 more transfers per year? How many beds will the NICU need in 10 years if growth continues at the current rate? How will the unit's cost structure change if nursing assistants are hired to do certain tasks, so that each registered nurse can take an additional patient and the minimum nurse-to-patient ratio drops from 1:3 to 1:4? Other less-quantifiable benefits of using a simulation model to study the operation of a NICU include improved patient safety (through appropriately resourcing the unit) and better employee satisfaction (through improved predictability of nursing assignments and reduction of stress associated with understaffing).

2 MODEL OVERVIEW

The objects, or entities, that flow through the NICU model represent patients (babies), and each patient entity has properties, or attributes, that include gestational age (GA), days of life upon arrival, and acuity. Other inputs to the model include estimated probability distributions for the number and type of admissions per day, as well as the probability (based on GA) that each simulated baby will develop one of five major morbidities that are known to affect the length of stay and acuity of NICU patients.

In our simulated NICU, we model the flow of patient entities through the NICU over a 1-year time period. The constraints in our model include the number and type of beds in the NICU (critical-care or step-down), the number of transfer beds available each simulated day, and the number of nurses. The following response data are collected by the simulation model: number of admissions, number of admissions with a GA less than 28 weeks, total number of transferred patients, total number of patients who die, and length of stay of all patients. One additional response of interest is the average daily census. Unlike the other responses for this model that are based on a simulation run length of one year, average daily census is a long-run performance measure, and steady-state analysis methods are used to estimate it. Whether the model is being run for one simulated year (the terminating case) or for a long period of time to estimate steady-state performance measures (the nonterminating case), it is important to accurately estimate the length of the warm-up period and include in the analysis only observations that are generated after the end of the warm-up period. The SAS Simulation Studio Steady State block is used for detecting the end of the warm-up period as well as for computing confidence intervals for steady-state performance measures.

3 KEY FINDINGS AND RECOMMENDATIONS

From our initial simulation results, it is evident that we have been able to successfully model the current operation of Duke's NICU. This critical first step provides a snapshot of the present state for NICU managers. We plan to continue to work with this model and use it to study how changes in the unit's physical structure (number of beds), staffing, referral patterns, or patient mix will affect the NICU in a future state. For example, we ran the simulation using a staffing level of 26 nurses per shift (this is close to the actual staffing level at Duke). We also ran the simulation model using 30 nurses to demonstrate the effect of adding 4 nurses per shift. The daily census increased from 58.2 to 60.7 patients on average and yearly admissions increased from 845.4 to 881.3 on average. Such information, combined with the NICU's proprietary cost information, can be used by the NICU's management to study how the unit should be staffed for growth.

We also ran the model using best and worst case scenario morbidity input data. In the best case scenario, the average length of stay is approximately 27 days and the total cost is approximately $12.4 million while in the worst case scenario, the average length of stay is 24 days and the total cost is approximately $15.5 million. So while the average length of stay in the best performing units is longer, the total cost per patient is less than for the worst performing units. This is contrary to the current belief that a reduction in length of stay implies a reduction in cost due to improved care.

It is also important to note that although this discrete-event simulation model is based on the Duke NICU, it can easily be applied to other level-3 or level-4 inborn NICUs across the country after modifying a few critical variables that are unique to an individual NICU, including number of beds, number of nurses, transfer patterns, and admission distributions.