INCORPORATING PATIENT DETERIORATION WHEN SIMULATING UTILIZATION OF A CARDIOVASCULAR INTENSIVE CARE UNIT

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Introduction

Patients undergoing many forms of cardiovascular surgery typically enter the cardiac intensive care unit (ICU) after surgery, transfer to a step down (SDn) unit, and then are ultimately either discharged or bounce back to the CICU because of deterioration. The average patient flow is shown in figure 1.

Figure 1: Cardiac ICU Flow

Finite capacity, variability, and unpredictability limit the amount of patients that can move through the Cardiovascular Center (CVC) at Michigan Medicine. One major source of unpredictability is patient deterioration or bounce back. This occurs after a patient is initially moved to SDn, but due to deterioration, must be sent back to the ICU. Bed management is the allocation of units and affiliated services that go with being treated by the medical facility and is one way to compensate for this variability within the system.

Objective

This study aims to model patient flow throuh the ICU, and its corrensponding step down unit (SDn), to analyze the effects of bounce back on the bed utilization within each unit.

Simulation

The team developed a discreet event simulation designed to model the flow of patients through the ICU and SDn. Historical data from Michigan Medicine's DataDirect was analyzed to determine bounce back probabilities and arrival rates.

Inputs		Metrics
Fixed	**Variable**	• Patient Arrivals
• Bed Count per unit	• Arrival Rate: Exponential Distribution	• Accepted/Denied Patients
• Time horizon	• Length of Stay in each unit : Geometric Distribution	• Patient LOS per unit
• Bounce back probabilities		• Unnecessary Days in unit
		• Bed Utilization per unit

Table 1: Inputs and Metrics for Simulation

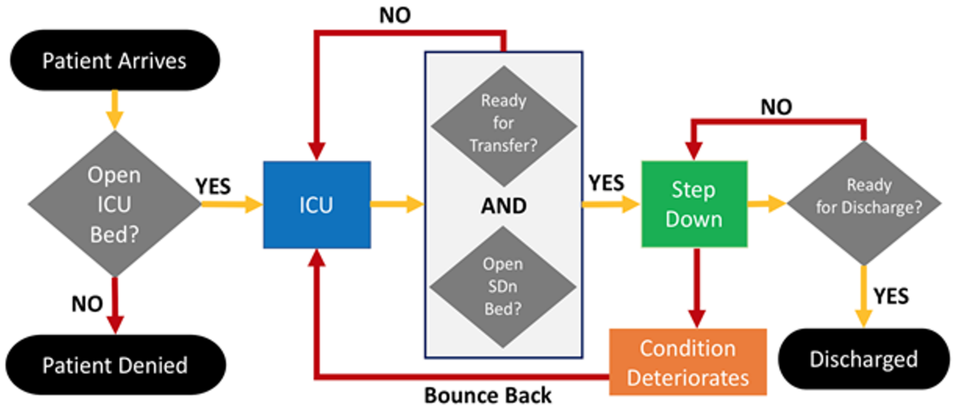


Figure 2: Simulation Logic

Analysis

Allocated ICU Beds	30	32	34	36
Annual Patient Arrival	2299	2299	2299	2299
Patients Denied	**14.35%**	**10.79%**	**7.57%**	**5.13%**
ICU Average LOS ICU Status (Days)	3.94	4.02	3.98	4.01
ICU Beds Utilization	**83.93%**	**81.93%**	**79.54%**	**77.07%**

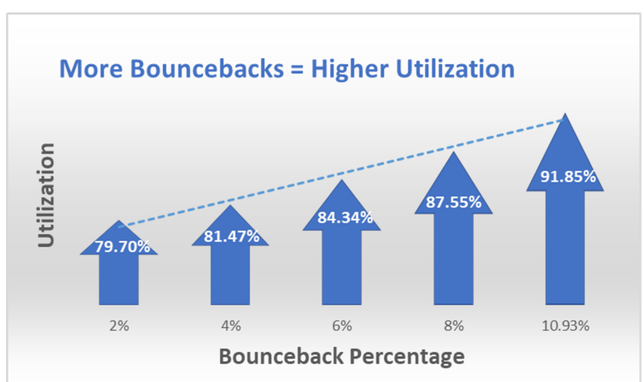
Table 2: Optimal number of ICU beds

Analysis 1: Determine optimal number of ICU beds
- SDn capacity sett to 1000 to avoid bottle necks
- **36 ICU Beds** provide the best balance between denial and utilization

Analysis 2: Determine optimal number of SDn beds
- ICU capacity set to 36 based on Analysis 1
- **36 SDn Beds** provide the best balance between denial rate and utilization

Allocated SDn Beds	32	34	36	38
Annual Patient Arrival	2299	2298	2299	2300
Patients Denied	**5.83%**	**5.48%**	**5.26%**	**5.17%**
SDn Average LOS	5.81	5.93	5.98	5.99
SDn Beds Utilization	**84.69%**	**80.77%**	**76.94%**	**73.22%**

Table 3: Optimal number of SDn beds



Graph 1: Bounceback vs Utilization

Analysis 3: Determine effect of bounce back
- ICU and SDn capacity set to 36 each based on Analysis 1 and 3
- Higher bounce back percentage led to higher patient denials and utilization across each unit

[Poster Code U05]

Conclusions

- The benefits of adding ICU/SDn beds will plateau after a certain point, the marginal benefits of lowering the percentage of patients denied will be outweighed by the drawbacks of low bed utilization
- Even a small amount of uncertainty (change of bounce back probability) in the hospital system has a significant impact on patient flow
- The effect of bounce back is significant enough to be considered when determining bed management policies

Next steps include:

- Adding the elective surgery process to the model, which may influence the arrival rates and length of stay of patients
- Incorporating different patient flows through the CVC, including patient who move from the OR to SDn

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References

Bae, K. H., M. Jones, G. Evans, and D. Antimisiaris. 2017. "Simulation Modelling Of Patient Flow and Capacity Planning For Regional Long-term Care Needs: A Case Study". *Health Systems* 8(1):1–16.

Fakhry, S. M., S. Leon, C. Derderian, H. Al-Harakeh, and P. Ferguson. 2013. "Intensive Care Unit Bounce Back in Trauma Patients: An Analysis of Unplanned Returns to the Intensive Care Unit". *Journal of Trauma and Acute Care Surgery* 74(6):1528-1533.

Halpern, N. A., and S. M. Pastores. 2015. "Critical Care Medicine Beds, Use, Occupancy and Costs in the United States: A Methodological Review". *Critical Care Medicine* 43(11):2452-2459.

Magruder, J. T., M. Kashiouris, J. C. Grimm, D. Duquaine, B. McGuinness, S. Russell, M. Orlando, M. Sussman, and G. J. Whitman. 2015. "A Predictive Model and Risk Score for Unplanned Cardiac Surgery Intensive Care Unit Readmissions". *Journal of Cardiac Surgery* 30(9):685-690.

Rosenberg, A. L., and W. Charles. 2000. "Patients Readmitted to ICUs: A Systematic Review of Risk Factors and Outcomes". *Chest* 118(2):492-502.

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