Capacity Management in a Cardiac Surgery Line

by

Carter Price, *University of Maryland*

Timothy Babineau, *University of Maryland Medical Center*

Bruce Golden, *University of Maryland*

Bartley Griffith, *University of Maryland Medical Center*

Michael Harrington, *University of Maryland Medical Center*

Edward Wasil, *American University*

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Problem Statement

- The Cardiac Surgery service line at the UMMC has 12 beds devoted to the intensive care unit (ICU).
- The Cardiac Surgery service line ICU is operating near capacity and serves as a bottleneck for the flow of patients.
- Cardiac Surgery is a high dollar service line. Disruptions in the flow result in a significant reduction in revenue.

Problem Statement--continued

- The staffing patterns are made more than a week in advance.
- The staffing is then adjusted based on perceived need.
- These decisions are made on a same day basis as information becomes available.
- Key Question: Can information on the number of discharges be predicted a few days in advance?

Solution Approach

- The lengths of stay (LoS) for individual patients were predicted.
- Using these predictions, a posterior distribution was constructed for each patient (given the patient has stayed in the hospital a certain length of time, how much longer do we expect the patient to stay).
- The individual LoS predictions were aggregated for the ICU.
- These predictions were tested using simulation and in a hospital setting.

Data Set

- The data set contained detailed information about the length of stay for every cardiac surgery patient from FY05 and FY06.
- There were 1,675 cardiac patients in this time frame.
- The data set included current protocol (CPT) codes, LoS, age, sex, and race.
- Because there were a few hundred different CPT codes present they were initially narrowed into 20 different groups.

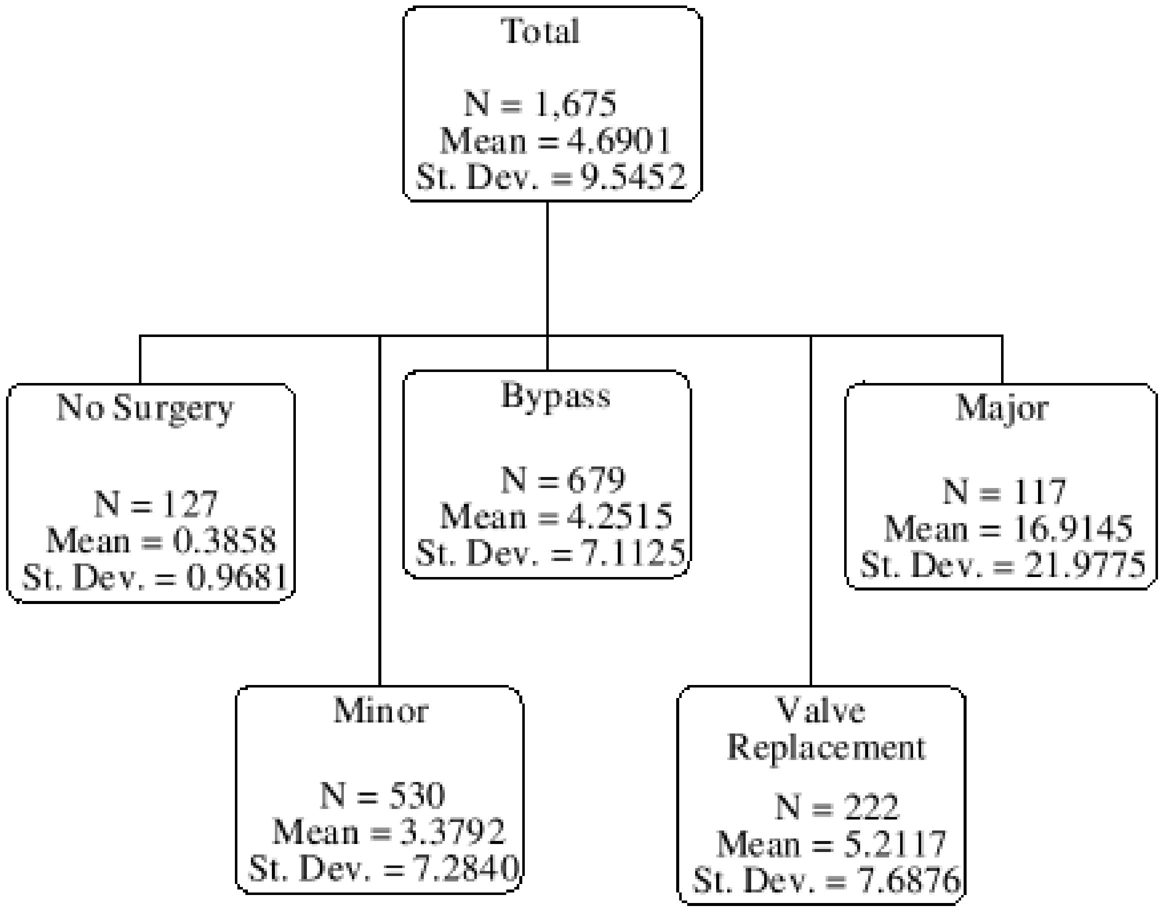
LoS Prediction

- We tested four methods for predicting patient LoS: Neural Networks, Model Tree, CHAID tree, and Median Regression.
- WEKA was used for the Neural Net, Model Tree and Median Regression.
- AnswerTree was used for the CHAID tree.
- Each of these methods was trained on 66% of the data and tested on the remaining 34%.
- The tests were repeated 10 times with different test sets.

Prediction Results

	Neural Networks	Least Median Squared	Group Mean	Model Tree	CHAID
MAD	4.3107	3.8660	4.2638	4.4185	4.5982
RMSE	9.1068	10.3334	9.0283	9.2361	9.6728
Test MAD	4.0925	3.7431	4.1232	4.1779	4.2576
Test RMSE	8.3763	9.8771	8.4512	8.5400	8.8847
Parameters	406	25	21	10	5

CHAID Divisions



Posterior Distribution

- No parametric distribution provided a good fit for any of the LoS groups.
- Kaplan-Meier estimators were used to construct the posterior distribution.
- These estimators were smoothed.

Aggregating Predictions

- The individual LoS predictions were aggregated using a multinomial distribution.
- The expected census was determined by summing the probabilities each patient would stay at least one more day.
- The variance of the census was calculated by summing the probability each patient would stay times the probability the patient would be discharged.

Testing

- We tested the census predictions using simulation and then on a daily basis at the hospital for four weeks in June and July of 2007.
- 1, 2, and 3 day predictions were made.
- The population for the simulation was length biased because a patient with a long LoS was more likely to be observed.
- The simulation was run 10,000 times.

Simulation Results

	1 Day	2 Days	3 Days
Mean Absolute Error	1.3173	1.3735	1.3213
Bias	0.0962	0.1374	0.2579
% Overestimated	25.25%	30.20%	36.93%
% Accurate	48.12%	47.33%	42.38%
% Underestimated	26.63%	22.48%	20.69%

Actual Results

	1 Day	2 Days	3 Days
Mean Absolute Error	1.15	1.80	2.50
Bias	-0.17	-0.49	-0.87
% Overestimated	17%	20%	0%
% Accurate	33%	30%	25%
% Underestimated	50%	50%	75%

Implications of the Errors

- The discharge predictions tended to be too low.
- More patients than predicted were discharged on days with a high scheduled volume.
- Robotic surgery is much more common now and those patients generally have a shorter LoS. This means that the posterior distributions for groups 3 and 4 have too much positive skew.

Conclusions

- The model was able to accurately determine when cases would be cancelled because there were more cases scheduled than available capacity.
- The initial results imply that the current model is not accurate enough to determine the required staffing levels.

Further Work

- The expected case volume should be included to improve the predictions.
- The effects of technological improvements on LoS should be determined.
- More advanced distribution fittings such as a gamma mixture model should be tested.
- Work is being done to predict capacity in other service lines.