Simulating Access and Patient Flow for a Cardiovascular ICU

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CHEPS

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...
Research
Education
Implementation
Outreach
Dissemination
RESEARCH MOTIVATION

What is the aortic dissection (AD) patient experience?

Ensure adequate capacity for all transfer requests to the Cardiovascular Center (CVC) at Michigan Medicine (MM)
INITIAL RESEARCH QUESTION

Patient Needs

- OR
- Surgeon
- Staff
- ICU Bed

= Aortic Dissection Patients
INITIAL RESEARCH QUESTION

It’s a lot more complicated than that…

= Aortic Dissection Patients
THE BIGGER PICTURE

= Aortic Dissection Patients
= All Other Cardiac Patient Types

Patient Needs
- OR
- Surgeon
- Staff
- ICU Bed
PATIENT FLOW IN CARDIOVASCULAR SURGERY

1. Arrival
2. OR
3. ICU
4. Step Down
5. Discharge
TRANSFER REQUESTS

Preliminary analysis conducted by the CVC staff showed that the most common reason for patient deferral when requesting transfer to Michigan Medicine is attributed to unavailable ICU beds.
APPROACH TO IMPROVING ICU UTILIZATION

Current State

Future State

Educate Clinical Partners About Uncertainty

Test Policies to Increase Patients’ Access to High Quality Care

Build Simulation Tool
SIMULATION FRAMEWORK

FIXED INPUTS
• Bed Count per Unit
• Time Horizon
• Number of Replications

VARIABLE INPUTS
• Patient Arrival Rate
• Length of Stay in ICU and Step Down (SDn) units
• Bounce Back Probability
SIMULATION FRAMEWORK

Assumptions
- OR, surgeon and staff are always available
- Any patient can be denied

Patient Arrives

Open ICU Bed?

YES

ICU

NO

Ready for Transfer?

AND

Open SDn Bed?

NO

Bounce Back

YES

Step Down

Ready for Discharge?

YES

Discharged

NO
## SIMULATION FRAMEWORK

### METRICS

<table>
<thead>
<tr>
<th>Number of…</th>
<th>ICU</th>
<th>Step Down (SDn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Arrivals</td>
<td>• Patient LOS</td>
<td>• Patient LOS</td>
</tr>
<tr>
<td></td>
<td>• Unnecessary days in an ICU bed (SDn status)</td>
<td>• Unnecessary days in a SDn bed (ICU status)</td>
</tr>
<tr>
<td></td>
<td>• Bed Utilization</td>
<td>• Bed Utilization</td>
</tr>
<tr>
<td>Accepted Patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denied Patients</td>
<td></td>
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</table>
## ANALYSES

<table>
<thead>
<tr>
<th>1</th>
<th>SDn Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Change number of shared SDn beds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Bounce Back Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Change the rate of bounce back incrementally</td>
</tr>
</tbody>
</table>
BASE CASE PARAMETERS

• 1 Patient Type
• Arrival Rate = 0.33 patient/hr
• Time Horizon = 1 Year
• Replications = 1,000

• Bernoulli trial for transfer and discharge from respective units
  • $P_{\text{ICU Transfer}} = 0.25$
  • $P_{\text{SDn Discharge}} = 0.25$

Bed Count

- 36 ICU Beds
- 52 SDn Beds
- 16 Dedicated SDn Beds
- 36 Shared SDn Beds
### ANALYSIS 1: SDN VARIATION

<table>
<thead>
<tr>
<th>Allocated Step Down Beds</th>
<th>28</th>
<th>32</th>
<th>36</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Patient Arrival</td>
<td>2879</td>
<td>2875</td>
<td>2878</td>
<td>2877</td>
</tr>
<tr>
<td>Patients Denied</td>
<td>8.1%</td>
<td>5.8%</td>
<td>4.8%</td>
<td>4.5%</td>
</tr>
<tr>
<td>ICU Average LOS ICU Status</td>
<td>3.45 days</td>
<td>3.44 days</td>
<td>3.44 days</td>
<td>3.44 days</td>
</tr>
<tr>
<td>ICU Average LOS SDn Status</td>
<td>0.34 days</td>
<td>0.14 days</td>
<td>0.04 days</td>
<td>0.01 days</td>
</tr>
<tr>
<td>SDn Average LOS</td>
<td>3.70 days</td>
<td>3.78 days</td>
<td>3.82 days</td>
<td>3.83 days</td>
</tr>
<tr>
<td>SDn Bed Utilization</td>
<td>94.23%</td>
<td>88.98%</td>
<td>82.06%</td>
<td>74.73%</td>
</tr>
</tbody>
</table>

- Time Horizon = 1 Year
- Replications = 1,000
- 36 ICU Beds
- 16 Dedicated SDn Beds
### ANALYSIS 2: BOUNCE BACK

<table>
<thead>
<tr>
<th>Bounce Back Rate</th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
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</thead>
<tbody>
<tr>
<td>Annual Patient Arrival</td>
<td>2875</td>
<td>2871</td>
<td>2873</td>
<td>2872</td>
</tr>
<tr>
<td>Patients Denied</td>
<td>5.8%</td>
<td>13%</td>
<td>22%</td>
<td>31%</td>
</tr>
<tr>
<td>ICU Average LOS ICU Status</td>
<td>3.44 days</td>
<td>3.85 days</td>
<td>4.09 days</td>
<td>4.39 days</td>
</tr>
<tr>
<td>ICU Average LOS SDn Status</td>
<td>0.14 days</td>
<td>0.31 days</td>
<td>0.68 days</td>
<td>1.15 days</td>
</tr>
<tr>
<td>SDn Average LOS</td>
<td>3.78 days</td>
<td>4.19 days</td>
<td>4.43 days</td>
<td>4.45 days</td>
</tr>
<tr>
<td>SDn Average LOS ICU Status</td>
<td>0 days</td>
<td>0.15 days</td>
<td>0.45 days</td>
<td>0.76 days</td>
</tr>
<tr>
<td>ICU Bed Utilization</td>
<td>78.88%</td>
<td>85.95%</td>
<td>89.53%</td>
<td>92.02%</td>
</tr>
</tbody>
</table>

- Time Horizon = 1 Year
- Replications = 1,000
- 36 ICU Beds
- 32 SDn Beds
ANALYSES TAKEAWAYS

Analysis 1: SDn Variation
• The unnecessary ICU bed days decreases as SDn beds are added to a certain point
• Trade-offs will be necessary

Analysis 2: Bounce Back
• Small rates of bounce back impact utilization and flow
• Patient information would allow us to more accurately predict bounce back rates
FUTURE RESEARCH

• Expanding the tool
  • Adding more patient types
  • Adding patient predictors of bounce back

• Conducting Analysis
  • More data!
  • Explore smoothing elective surgery
ACKNOWLEDGEMENTS

Thank you to Ambika Agrawal, Amanda Moreno-Hernandez, Harini Pennathur, Hadi Saab, Ziqi Wang, Shuhao Zhou, and all prior CHEPS students who have contributed to this work!
Questions?
## LITERATURE REVIEW

<table>
<thead>
<tr>
<th>First Author</th>
<th>Reference</th>
<th>Year</th>
<th>Objective/Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levin, S.</td>
<td>[5]</td>
<td>2011</td>
<td>To test policies to reduce patient's length of stay (LOS) and increase patient throughput.</td>
</tr>
<tr>
<td>Marmor, Y.</td>
<td>[6]</td>
<td>2013</td>
<td>To predict minimum bed needs to achieve the high patient service level demanded for the cardiovascular ICU.</td>
</tr>
<tr>
<td>Levin, S.</td>
<td>[7]</td>
<td>2015</td>
<td>To estimate patients’ wait time while integrating the effect of the transition process (i.e. wait time for a bed to become available) with queuing using embedded regression models.</td>
</tr>
<tr>
<td>Kolker, A.</td>
<td>[8]</td>
<td>2009</td>
<td>To establish a quantitative link between the daily load leveling of elective surgeries (i.e. elective schedule smoothing) and ICU diversion of multiple ICU units including cardio ICU.</td>
</tr>
</tbody>
</table>
REFERENCES


