SIMULATING THE FLOW OF PATIENTS WITH AORTIC DISSECTION THROUGH A CARDIAC INTENSIVE CARE UNIT

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CHEPS

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

Research
Education
Implementation
Outreach
Dissemination

A prescription to address system complexity in healthcare
OUTLINE

Research Motivation
Introduction
Problem Statement
Literature Review
Simulation Framework
Analysis
Future Research
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)
WHAT IS AN AORTIC DISSECTION?

Aortic dissection (AD) is an emergency cardiovascular condition affecting the aorta. It is the result of a tear in the inner wall of the aorta causing severe internal bleeding and potential death.

Mortality rate for AD increases 1% per hour [1] and 20% of AD individuals die before reaching the hospital [2]. Aortic dissections are rare, but when they occur, they are medical emergencies.
CARDIOVASCULAR PATIENTS

• Cardiovascular disease is the leading cause of death in the US [3].
• By 2030, approximately 40.5% of the US population is projected to have some type of cardiovascular disease [4].
• The most common surgeries in the United States (US) are cardiovascular [3].
PATIENT ARRIVAL STREAM AND FLOW IN CARDIOVASCULAR SURGERY

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

Preliminary analysis conducted by the CVC staff showed that the most common reason for AD patient deferral when requesting transfer to Michigan Medicine is attributed to unavailable ICU beds.
IMPORTANCE OF A GLOBAL HEALTH PERSPECTIVE

Test Policies to Increase AD Patients’ Access to High Quality Care

Current State

Future State

Educate Clinical Partners About Uncertainty
## 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>
SIMULATION FRAMEWORK

INTRODUCTION | PROBLEM STATEMENT | LITERATURE REVIEW | SIMULATION | ANALYSIS | FUTURE RESEARCH
DATA PRE-PROCESSING

- MiChart, a product of Epic, is Michigan Medicine’s patient-centric electronic health record
- Data Direct enables access to clinical data
- SQL Database contains all patients that visited the CVC ICU between Jan 2016 and May 2019
SIMULATION FRAMEWORK

**FIXED INPUTS**
- Bed Count per Unit
- Time Horizon
- Replications

**RANDOM INPUTS**
- Patient Type
- Arrival Rate
- Service Time per Unit
**SIMULATION FRAMEWORK**

**LOGIC**

- **Patient Arrives**
  - **Open ICU Bed?**
    - YES → **ICU** → **Ready for Transfer?**
      - NO → **Step Down**
      - YES → **Open SDn Bed?**
    - NO → **Patient Denied**
  - NO → **Patient Denied**

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

**Ready for Discharge?**

- NO → **Discharged**
- YES → **Ready for Discharge?**
## SIMULATION FRAMEWORK

### METRICS

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
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<tbody>
<tr>
<td>Patients Requesting Care (Patient Arrival)</td>
<td>Accepted Patients</td>
</tr>
<tr>
<td></td>
<td>Declined Patients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ICU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stepdown (SDn)</td>
</tr>
<tr>
<td>• Patient LOS</td>
<td>• Patient LOS</td>
</tr>
<tr>
<td>• Unnecessary days in an ICU bed (SDn status)</td>
<td>• Bed Utilization</td>
</tr>
<tr>
<td>• Bed Utilization</td>
<td></td>
</tr>
</tbody>
</table>

- **sd**: Standard deviation
- **min**: Minimum
- **mean**: Mean
- **max**: Maximum
- **med**: Median
ANALYSES

1. SDn Variation
   - Change number of shared SDn beds

2. Bed Trade Off
   - Change the ratio of ICU beds to SDn beds

3. Arrival Rate
   - Change the hourly patient admission rate
BASE CASE PARAMETERS

- 1 Patient Type
- Arrival Rate = 0.31 patient/hr
- Time Horizon = 1 Year
- Replications = 1,000

Bernoulli trial for transfer and discharge from respective units
- $P_{\text{ICU Transfer}} = 0.22$
- $P_{\text{SDn Discharge}} = 0.24$
ANALYSIS 1: SDN VARIATION

<table>
<thead>
<tr>
<th>Allocated Stepdown Beds</th>
<th>25</th>
<th>34</th>
<th>43</th>
<th>52</th>
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</thead>
<tbody>
<tr>
<td>Patient Arrival</td>
<td>2718</td>
<td>2718</td>
<td>2714</td>
<td>2716</td>
</tr>
<tr>
<td>Declined Percentage</td>
<td>16%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>ICU Average LOS</td>
<td>3.94 days</td>
<td>3.93 days</td>
<td>3.93 days</td>
<td>3.93 days</td>
</tr>
<tr>
<td>ICU Status</td>
<td>3.94 days</td>
<td>3.93 days</td>
<td>3.93 days</td>
<td>3.93 days</td>
</tr>
<tr>
<td>ICU Average LOS</td>
<td>0.33 days</td>
<td>0.02 days</td>
<td>0 days</td>
<td>0 days</td>
</tr>
<tr>
<td>SDn status</td>
<td>3.68 days</td>
<td>3.98 days</td>
<td>4 days</td>
<td>4 days</td>
</tr>
<tr>
<td>SDn Average LOS</td>
<td>3.68 days</td>
<td>3.98 days</td>
<td>4 days</td>
<td>4 days</td>
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</tbody>
</table>

- Time Horizon = 1 Year
- Replications = 1,000
- 32 ICU Beds
- 16 Dedicated SD Beds

Allocated Stepdown Beds
- 25%
- 50%
- 75%
- 100%

IF Shared Beds Available

INTRODUCTION | PROBLEM STATEMENT | LITERATURE REVIEW | SIMULATION | ANALYSIS | FUTURE RESEARCH
ANALYSIS 2: BED TRADE OFF

- There are always 84 beds in total
- For every ICU bed added, there is one SDn bed removed
- After 44 ICU beds, the percentage of denied patients becomes less than 1% however cost continues to grow

ICU Beds: 28  SDn Beds: 56
ICU Beds: 44  SDn Beds: 40

0.48% Denied

ICU Daily Cost $4,300/bed
SDn Daily Cost $1,909/bed
## ANALYSIS 3: ARRIVAL RATE

<table>
<thead>
<tr>
<th>Arrival Rate</th>
<th>0.31</th>
<th>0.40</th>
<th>0.52</th>
<th>0.68</th>
<th>0.88</th>
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<tbody>
<tr>
<td>Patient Arrival</td>
<td>2718</td>
<td>3503</td>
<td>4556</td>
<td>5955</td>
<td>7710</td>
</tr>
<tr>
<td>Declined Percentage</td>
<td>16.26%</td>
<td>32.51%</td>
<td>47.54%</td>
<td>59.80%</td>
<td>68.88%</td>
</tr>
<tr>
<td>ICU Average LOS</td>
<td>3.94 days</td>
<td>3.99 days</td>
<td>4.07 days</td>
<td>4.14 days</td>
<td>4.19 days</td>
</tr>
<tr>
<td>ICU Status</td>
<td>3.99 days</td>
<td>3.99 days</td>
<td>4.07 days</td>
<td>4.14 days</td>
<td>4.19 days</td>
</tr>
<tr>
<td>ICU Average LOS</td>
<td>0.33 days</td>
<td>0.39 days</td>
<td>0.42 days</td>
<td>0.42 days</td>
<td>0.42 days</td>
</tr>
<tr>
<td>SDn status</td>
<td>0.33 days</td>
<td>0.39 days</td>
<td>0.42 days</td>
<td>0.42 days</td>
<td>0.42 days</td>
</tr>
<tr>
<td>SDn Average LOS</td>
<td>3.68 days</td>
<td>3.61 days</td>
<td>3.59 days</td>
<td>3.58 days</td>
<td>3.58 days</td>
</tr>
</tbody>
</table>

- Time Horizon = 1 Year
- Replications = 1,000
- 32 ICU Beds
- 25 SDn Beds

Arrival Rate Increased by 30%
FUTURE RESEARCH

• Expanding the tool
  • Relaxing assumptions
  • Patient type
  • Admission logic

• Conducting Analysis
  • More Data!!!
  • Collaborator goals: Explore smoothing elective surgery
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REFERENCES


Questions?