Understanding Pandemic Driven Demand and Optimizing Patient Flow

Learning from the Pandemic to Improve Healthcare

July 26, 2021

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Chapter 1
Modeling Patient Flows Through the Health Care System

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Abstract Health care systems can be evaluated from four perspectives: macro, regional, center, and department. In each case, reduction of patient delay depends on improving interfaces as patients are transferred from activity to activity or department to department. This chapter presents basic tools for resolving delays at interfaces, through mapping the processes by which patients are served, and by developing and implementing measures of system performance. These tools are demonstrated through a case study of the Los Angeles County/University of Southern California Hospital.

Keywords Process charts • Performance measurement • Health care systems
BASICS

PATIENT FLOW

Processes and steps by which patients receive healthcare services

AIM

To efficiently provide services when and where needed by patient

HIERARCHY OF DELAY

Availability of services, by time and place, does not match patient needs

- Perpetual: inadequate capacity, creating perpetual delays
- Varying: capacity is predictably not aligned with variability in needs
- Random: mismatch between capacity/need is un-predictable
OPTIMALLY

• Care is timely and appropriate, meeting patient needs
• Wait once arriving for care is short, safe and pleasant
• Capacity is fully utilized (not idled often for lack of patients)
WHEN SHORTAGE IS PERPETUAL

Care is significantly delayed

Some patients will give up, or never receive service

Patients will suffer
BASIC STRATEGIES

Supply
• Workforce availability/scheduling
• Facilities
• Supplies and equipment

Demand
• Prevention
• Appointment scheduling (and follow-up)
• Pricing

Synchronization
• Triage
• Coordination of related services
WHAT ABOUT COVID-19?

**Capacity**
- New resource requirements for in person
- Change in service provision (telemedicine)
- Supply shortages
- Staff shortages

**Demand**
- Deferred care (possibly generating future needs)
- Difficult to predict
- Public behavior affects transmission and can create surges
- Controlling infections in facilities

**Synchronization**
- Co-morbidities
- Discharging infectious patients
Patient Flow

- Well/Uninfected
  - Non Covid-19 cases – Emergent or scheduled
  - Transmission – new cases
- COVID-19 Case
  - Hospitalization
    - Case specific resources
    - Quarantine Facility
    - Infected at residence
    - Fatality
  - Post-hospitalization facility
  - Recovered
  - Plasma therapy
  - Plasma containing antibodies
Interventions

- Detection
- Testing
- Monitoring
- Distancing
- Movement
- Contact tracing
- Hygiene/PPE
- Vaccine
- Postponement
- Diversion
- Transfer
- Prevention
- Telemedicine for care
- continuity
- Monitoring
- Testing
- Therapeutics
- Telemedicine
- Quarantine
- Monitoring
- Testing
- Therapeutics
- Telemedicine
- Release from quarantine
- standard
- Therapies
- Fast discharge
- Fast testing
- Substitute, adapt
- or re-use
- Surge capacity
- Optimize
- resource allocation/creation
- Diversion
- Transfer
- Prepare for hospital discharges
- Monitoring
- Testing
- Therapeutics
- Telemedicine

COVID CASE  Non-COVID  AT HOME  QUARANTINE  HOSPITALIZED  POST-HOSPITAL
Success Measures

- **Reduced & Equitable**
  - Total cases
  - Rate/Acceleration of new cases
  - R – Value
  - Pandemic duration

- **Reduced & Equitable**
  - Non Covid-19 hospitalization
  - Comorbidities
  - Fatalities in non-Covid-19 cases

- **Reduced & Equitable**
  - Hospitalization
  - Time to recovery
  - Fatality %

- **Reduced & Equitable**
  - Transmission
  - Hospitalization
  - Time to recovery
  - Fatality %

- **Reduced & Equitable**
  - Length of stay
  - Wait for bed
  - Fatality %
  - Availability
  - Beds, ventilators, other resources

- **Reduced & Equitable**
  - Rehospitalization
  - Wait for bed
  - Fatality %
  - Time to recovery
  - Length of stay
  - Availability
  - Beds, other resources

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COVID CASE  Non-COVID  AT HOME  QUARANTINE  HOSPITALIZED  POST-HOSPITAL
DISEASE TRANSMISSION: ASSESSING NEEDS

Prevalence of Disease (current infections)

Susceptible Population (lacking immunity)

Level of Contact Between Susceptible and Infectious
  • Proximity
  • Duration
  • Environment
  • Hygiene

PROCESS IS NON-LINEAR
GEOMETRIC GROWTH

Suppose new cases grow 5% per day:

1 case becomes: 4 new cases per day in one month
                80 per day in three months
                7200 per day in six months
                600,000 per day in nine months

Suppose new cases grow 8% per day:

1 case becomes: 10 new cases per day in one month
                1000 per day in three months
                1.2 million per day in six months

MODEST BEHAVIORAL CHANGES CAN RADICALLY CHANGE THE TRAJECTORY
STOPPING THE CYCLE OF GROWTH

Reducing the susceptible population
• Acquired immunity
• Vaccination

Changing Collective Behavior to Reduce Contact

RESTARTING THE CYCLE OF GROWTH

• Changing Collective Behavior to Increase Contact
• Variants that Reduce Immunity
Inter-regional Effects
Once disease is prevalent in region, importation may have insignificant effect
Community Spread, Equilibration of Import & Export of Disease, & Acceleration of Community Spread Within Special Populations, Now Exporting to General Population
INTEGRATED MODELING
Tracking Covid-19 Cases and Deaths in the United States: Distribution of Events by Day of Pandemic

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Article Type: Original Research

ABSTRACT

In this paper, we analyze the progression of COVID-19 in the United States over a nearly one-year period beginning March 1, 2020, with a novel metric representing the partial-average day-of-event, where events are new cases and new deaths. The metric is calculated as a function of date and location to illustrate patterns of disease, showing growing or waning cases and deaths. The metrics enable the direct comparison of the time distribution of cases and deaths, revealing data coherence and revealing how patterns varied over a one-year period. We also compare different methods of estimating actual infections and deaths to get a better perspective on the timing and dynamics of the pandemic by state. We used these metrics also to evaluate the accuracy of various forms of data, including census estimates.
NEW YORK

State: New York, CDC Data, as of Date Day 1 = 03/01/2020, Date Run: 07/25/2021
Distribution of Average Case Day by State and Data Source

![Graph showing distribution of average case day by state and data source. The x-axis represents the average day of case with Day 1 = 3/1/2020, and the y-axis represents cumulative probability. Three lines are plotted: Covidestim in orange, COVID-19 Projections in green, and CDC in blue.]
COVID-19 Projections

CDC
### Table 1 Statistics for Average Case and Death Day by State

<table>
<thead>
<tr>
<th></th>
<th>Covidestim</th>
<th>Covid-19 Projections</th>
<th>CDC</th>
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<tbody>
<tr>
<td></td>
<td>Average Day of Case in State</td>
<td>Average Day of Death</td>
<td>Average Day of Case in State</td>
</tr>
<tr>
<td>National Average</td>
<td>253</td>
<td>236</td>
<td>227</td>
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<tr>
<td>SD Among States</td>
<td>12</td>
<td>34</td>
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<tr>
<td>Minimum Among States</td>
<td>230</td>
<td>133</td>
<td>145</td>
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<tr>
<td>Maximum Among States</td>
<td>280</td>
<td>282</td>
<td>264</td>
</tr>
</tbody>
</table>
DECLINING EFFECTIVE REPRODUCTION NUMBER IN 2020

New York R-history

California R-history
## TAKE AWAYS

- **Patient flow options**
  - Supply: COVID transmission
  - Demand: Non-COVID
  - Synchronization: At home, Quarantined, Hospitalized, Post-hospitalized

- Demand highly sensitive to **collective** human behavior and conditions
- Surges experienced at different times at different places
- Behavior has changed (and will change) course of pandemic: acceleration vs. deceleration (declining rate of growth)
PATIENT FLOW SYSTEM
Our Goal

We aim to reduce the consequences of viral disease through interventions that simultaneously affect the rates at which new cases occur and affect the provisioning of healthcare resources to serve patient needs. Toward that end, we are developing models of disease transmission and capacity allocation, considering:

- Sensitivity to interventions that limit disease spread by constraining the movement of people and imposing their isolation
- Uncertainties that influence the growth in cases, and how these uncertainties are resolved or change over time
- Needs of skilled nursing and other congregate living settings

Want to find out more about the project? Check out some of the links below.
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Reducing Threats and Mitigating Emergencies

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Work supported by the Zumberge Innovation Fund and the Center for Undergraduate Research in Viterbi Engineering