Improving Tardy Administration of Inhaled Medications for Inpatients with Respiratory Illnesses.

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Presentation Outline

• Background and motivation for the study
  – Clinical and economic incentives for improving on-time medications.
  – of tardy inhaled medications and some remediation strategies.
    Explanation for the high incidence
• Research goal: Revise existing medication schedules for inhaled medications and establish dispatching strategies to level clinician workload and significantly reduce late treatments.
• Discuss variables, parameters, models
• Results
  – Simulated on-time performance for current and proposed medication schedules.
  – Review implementation concerns about model recommendations ±0 9 days from launch.
• Future research
Economic Motivation for the study

• U.S. government is one of the nation’s largest health care insurers.
• It oversees high-impact initiatives that aim to improve medical outcomes for patients and reduce unnecessary spending by providers.
  – Inpatient prospective payment system (iPPS) bases Medicare payments to hospitals on the patient’s diagnosis and illness severity rather than the total cost of the services consumed while treating the patient.
  – Hospital Readmissions Reduction Program (HRRP) uses the proportion of patients who are readmitted within 30 days of discharge as a proxy for quality of care, and reduces iPPS payments to those hospitals with bottom quartile risk-adjusted readmission rates.
    – HRRP applies to acute myocardial infarction (heart attack), congestive heart failure, pneumonia, and beginning FY 2014, COPD and elective knee or hip replacement.
• **HRRP Definitions**
  -- Aggregate payments for all discharges = sum of base operating DRG payments for all discharges.
  -- Excess Readmit Ratio = 1 - (Aggregate payments for excess readmissions/Aggregate payments for all discharges).
  – Adjustment factor is ramping up.
    – For FY 2013, the adjustment factor for excess readmits → 1% reduction;
    – For FY 2014, it increases to a 2% reduction.
    – For FY 2015, it increases again to a 3% reduction.
Clinical Motivation for the Study

• Adverse drug events are injuries caused by the use of a medication; typically harmful effects arising from medication errors (Aljadney et al, 2013).
  – Adverse drug events increases average LOS by 1.9 days (Classen et al, 997); an unreimbursed expense under iPPS.
• The most common medication errors -- 1 of every 3 -- are “wrong time” errors (Keers et al, 2013; Balas et al, 2004).
  – Disproportionate share of wrong time errors involve respiratory therapy drugs (Sakoski et al, 2005).
• Adherence to prescribed medications and dosing times essential to the management and control of COPD symptoms (Restrepo, et al, 2008).
  – COPD patients (such as chronic bronchitis or emphysema) have the highest rate of pre-mature readmissions (Jencks et al., 2009);
  – High COPD re-admissions places hospital at risk of HRRP adjustments.
Why are most RT meds late? Inhalation medications are delivered differently, take longer to administer

- AARC reports 5 - 15 minutes required to administer aerosolized medications under intermittent and continuous delivery systems (AARC Uniform Reporting Manual).

- Aerosolized medications pose the risk of adverse reactions, requiring close patient monitoring by RT during treatment – parallel treatments prohibited.

- Respiratory patients often have co-morbidities and may be housed in any of several different care units throughout the hospital. RTs often travel between departments to administer inhaled medications.

- Time studies at subject hospital confirm that these factors limit RT productivity to 2 treatments/hr - 3 treatments/hr per RT.

- Common medication schedules require all scheduled treatments with the same frequency to be administered concurrently throughout the hospital, creating significant workload peaks for clinicians.
Why are RT Meds Late? Common hospital-wide medication schedules lead to significant workload peaks

- Aerosol delivery of RT medications is the largest consumer of Respiratory Care capacity (Pikarsky et al., 2001).
- Standard medication schedules create large demand peaks for respiratory therapists (RTs).

**Example:** Suppose hospital schedules an average of 114 TID respiratory treatments/day (or about 37 treatments, 3 times/day), to be administered at 8 AM, 4 PM, and midnight.

If each treatment requires an average of 30 minutes to complete, then ...

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How many RTs are needed to ensure those treatments are all completed on time?
Allowable treatment “time windows” help spread out and level peak RT requirements.

- Depending on allowable deviation from scheduled time, may need a maximum of between 8 and 37 RTs on duty to deliver all 37 treatments on time.

- Even with this flexibility, RT units in many acute care hospitals lack sufficient staff to achieve a high level of on-time treatment performance.

### Example: Suppose today’s orders call for 37 respiratory treatments 3 x per day (at 8 AM, 4 PM, and midnight).

Peak staffing requirements
- 37 if time window is +/- 0.0 hr
- 13 if time window is +/- 0.5 hr
- 8 if time window is +/- 1.0 hr

CMS now considers non-time-critical medications administered within 30 - 60 minutes of scheduled time as “on time.”
What can be done to improve on-time RT medication performance?

• Increase RT staff?

• Devise and adopt a separate “staggered” dosing schedule for RT meds that reflects the greater time needed to administer the meds and levels out RT workload?

This report focuses on the latter.

– Model on-time performance for staggered medication schedules that vary by nursing unit.
– Devise and evaluate simple dispatching strategies for clinicians.
Staggered medication schedules based on patient location further level RT staffing requirements

<table>
<thead>
<tr>
<th>Location</th>
<th>Study Period</th>
<th>Avg TID trmts per day</th>
<th>Avg RT Patient Census</th>
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<td></td>
<td><strong>37.77</strong></td>
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</tbody>
</table>

With common medication schedules and clinicians permanently assigned to a care unit, we have N single channel queues, ...

In contrast, under staggered medication schedules with teams of clinicians moving from unit to unit, the system resembles an N-channel, single line queue (...I think...).

In principle, that configuration should reduce waiting and result in fewer late medications.
Other strategies that could improve on-time performance: Demand Pooling?

• Hospital administrators approved staffing to achieve 90% service level for on-time RT medication performance.

• Number of RT patients in each nursing unit is independent of RT census in other departments.

• “Pooling” temporal demands of two or more nursing units provides potential to achieve service level with fewer clinicians.
Reduced capacity and labor requirements due to demand pooling effects.

Minimum staff (capacity) needed to achieve 90% SL (ie, P(D < capacity) >= 90%

<table>
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<tr>
<th>Dept A</th>
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<th>Total Capacity Req’d</th>
<th>Depts share common due time</th>
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<td>1 &amp; 2</td>
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</tr>
<tr>
<td>1</td>
<td>8</td>
<td>10</td>
<td>1 &amp; 8</td>
</tr>
</tbody>
</table>

Pct Savings:
- 12.50%
- 5.56%
- 5.56%
- 13.33%
- 13.33%
- 13.33%
- 10.00%
Research Objectives

Improve on-time performance (complete treatments within +/- 1 hr of scheduled RT treatment time) while observing strict staffing constraints.

1. Establish medication schedules that vary by nursing unit and dispatching strategies for clinicians that can dramatically reduce tardy medications for patients in 8 nursing units.
2. Route clinicians as a team from unit to unit to foster teamwork and support a primary care treatment model.
3. Prior to implementation (10 9 days from now) validate strategies analytically and demonstrate performance using simulation.

- Optimize medication times with two-stage stochastic goal program.
- Evaluate dispatching strategies with simulation.
Stage 1 Model: Chance Constrained Goal Program for Staggered Medication Times

Objective: Minimize late treatments \hfill (1)

Subject to:

Assign a scheduled medication time for the \(k\)th treatment of the day to each care unit. \hfill (2)

Assign at most one subset of the care units to a particular scheduled medication time. \hfill (3)

Ensure the scheduled medication times fall within clinically effective intervals. \hfill (4) & (5)

Schedule medication times during patient waking hours; observe other time-of-day constraints on scheduled medication times. \hfill (6) & (7)

Avoid interfering with other higher-priority scheduled routines \hfill (8)

**Clinician Allocation Decisions:**

Allocate available clinicians to scheduled medications within the allowed time window (\(+/- \) 1 hour or \(+/- \) 2 planning intervals of the scheduled medication time). \hfill (9)

Compute scheduled workload for each period \hfill (10)

Compute number of late/omitted treatments conditioned on planned workload \(R_{t_0}\) \hfill (11)

Non-negativity and integrality constraints. \hfill (12)
Stage 2 Model: RCP Allocation Decisions

\[ \text{Minimize} \sum_{t=1}^{T} \sum_{d=1}^{D} Z_{td} \]  \hspace{1cm} (13)

Subject to:

Assign available RCPs to administer scheduled treatments within the allowed time window and record number of late treatments.

\[ \sum_{s=t-2}^{t+2} Y_{t,d,s} + Z_{t,d} = r_{dt}, \text{ for } d=1,\ldots,D \text{ and } t=1,\ldots,T \]  \hspace{1cm} (14)

Allocate at most \( W_t \) therapists during period \( t \), or

\[ \sum_{s=t-2}^{t+2} Y_{t,d,s} \leq W_t, \text{ for } t=1,\ldots,T \]  \hspace{1cm} (15)

\[ Y_{t,d,s} \geq 0, \text{ for } t=1,\ldots,T; d=1,\ldots,D; \text{ and } t-2 \leq s \leq t+2. \]  \hspace{1cm} (16)
Computational study, results, and discussion

- Model parameters based on six months of aggregated care data from a 350 bed acute-care hospital that treats patients with breathing disorders in 24 different care units.

- RT patient census (demand data)
  - About 25% of their RT patients were treated in six departments that for clinical reasons, had permanently assigned RCPs on the floor.
  
  - Most of the rest of the RT patients were treated in one of six other care units by clinicians who were not permanently assigned to a care unit. Although average census in each of these departments was provided, hospital lacked information about the demand variability; assumed arrivals followed Poisson.
  
  - The rest (on average, fewer than one patient/day), were treated in 12 other units dispersed throughout the hospital.
  
  - During the six month study period, 20,734 doses of inhaled medications were administered in the 18 care units without a permanently assigned RT clinician.
Baseline Study:
Distribution of late RT medications/day using Common Medication Schedules (09, 13, and 17, as used by Univ Washington Hosp)

Late medications for 100 replications of simulated patient census over 24 hrs of care. Average number of late medications = 43.6/day, standard deviation = 10.9
Optimal Staggered Medication Times with Staffing (D=5, E=4, N=2) and care unit demand at 90\textsuperscript{th} \%ile.

<table>
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<th>Unit d</th>
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Distribution of late medications with staggered medication times, Staffing (D=5, E=4, N=2) and care unit demand at 90th %ile.

Late medications for 100 replications of simulated patient census over 24 hrs of care. Average number of late medications reduced to 1.7/day.
Further Validation

• Assumed demand did not provide for PRN’s (literally, as required)
  – PRNs are considered pre-emptive events for RT clinicians
  – Another simulation study devised to incorporate PRN stochastics furnished by hospital.
A multi-channel pre-emptive priority queue

Variables:

- RT patient admissions Admits: $E(\text{arrival rate}) = 0.262 \text{ patients/hr or 6.285/day}$; so $IAT \sim 3.82 \text{ hrs}$
- LOS: $E(W) = 5.25 \text{ days or 128.6 hours}$, most discharges occur between 09:00 and 16:00
- Admit location (floor or nursing station 1 – 7) although recent study indicates most RT patients admitted to one of 6 depts) – under proposed system, clinicians travel to patient location. For study purposes, the largest dept is divided into two units.
- Time & location of PRNs (literally, medication is prescribed to be administered as needed). Emergencies often pre-empt scheduled treatments if all clinicians are busy, $IAT \sim 2.00 \text{ hrs}$

Parameters

- Service time (including Travel time, Make ready, Treatment time, Patient records), assumed constant $D = 30 \text{ min/treatment}$.
- Staffing levels (5 on days, 4 on eves, 2 on nits)
- Scheduled medication times: Proposed treatment times vary with nursing station.
RT begins scheduled treatment at $t$.

For $t < t(\text{PRN}) < t + 0.5$: Unscheduled PRN arrives, preempting scheduled treatment.

RT resumes pre-empted treatment at $t(\text{PRN}) + 0.5$.

Pre-empted treatment completed at $t + 1.0$.

Seize RT for PRN, begin treatment.

Release RT.
Simulating effect of PRN on Clinicians and Treatment Times

- Simulation intervals = ½ hr.
- PRNs arrive at any time; pre-emption complicates modeling of queue behavior.
- Treatment started at or before its Late Start time is considered on time, even if its finish time is more than one hour past the Late Finish time.
- Work-around: To simulate a PRN arriving t < t(PRN) < t + 0.5, finish any current treatments, then allocate one clinician to the PRN at time t+0.5 and dispatch remaining clinicians to any scheduled treatments. Release the clinician treating the PRN at t+1.0.
RT begins scheduled treatment at \( t \) (on time if \( t \leq LS \))

High Priority PRN arrives \( t < t(\text{PRN}) < t+0.5 \): pre-empting scheduled treatment

RT resumes pre-empted treatment at \( t(\text{PRN}) + 0.5 \)

Pre-empted treatment completed at \( t + 1.0 \)

Seize RT for PRN treatment

Release RT
# RT Medication Simulation for Staggered Medication Times and Pre-emptive Events

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<th>Clock</th>
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<th>ES</th>
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System allowed to run from empty for 1440 blocks (of 1/2 hr each; 720 hrs or 30 days) to reach system steady state, then data collected for an addition 720 hours. Main performance information for the first few runs shown below.

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<th>Repl</th>
<th>Sim blocks</th>
<th>Sim Days</th>
<th>Meds Admin</th>
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<td>3120</td>
<td>104.00</td>
<td>34</td>
<td>1.133</td>
<td>1.09%</td>
</tr>
<tr>
<td>r5</td>
<td>1440</td>
<td>30</td>
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<tr>
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<td>30</td>
<td>3463</td>
<td>115.43</td>
<td>82</td>
<td>2.733</td>
<td>2.37%</td>
</tr>
</tbody>
</table>

109.6541  2.160911  1.97%
What’s next?

• After lying dormant for nearly one year, hospital has hired staff and wants live trial of new staggered strategy by October 31.

• Testing electronic patient list that shows both planned treatments and completions, by department, in real time, has not begun. Plan is to base priorities on a simple critical ratio variant.

• 6-sigma team wants to see implications of a revised medication schedule that requires less back and forth between buildings; avoid administering scheduled treatments before 5:30 AM.

• Report nominated for a “best paper” award at DSI conference in November.