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Continuous Remote Patient Monitoring for Post-Discharge Heart Failure Management: Workflow Modeling using Discrete Event Simulation

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Introduction: Heart Failure (HF) Significance

- Nearly 6.5 million adults in the US and > 64 million worldwide are diagnosed with HF
- HF results in large # of hospitalizations and up to 25% of cases result in readmissions and high costs to health systems and societies globally

- Cascade-HF project goals:
- To determine the feasibility of a continuous remote patient monitoring program (CRPM)
- To determine if continuous remote patient data can reduce 30-day readmission rate
- To determine if continuous monitoring can improve care process
- To evaluate preliminary efficacy and technical outcomes

HF Monitoring

Heart Rate
Single Lead EKG
Respiratory Rate

Patient reported data

Rules based & Machine Learning algorithms

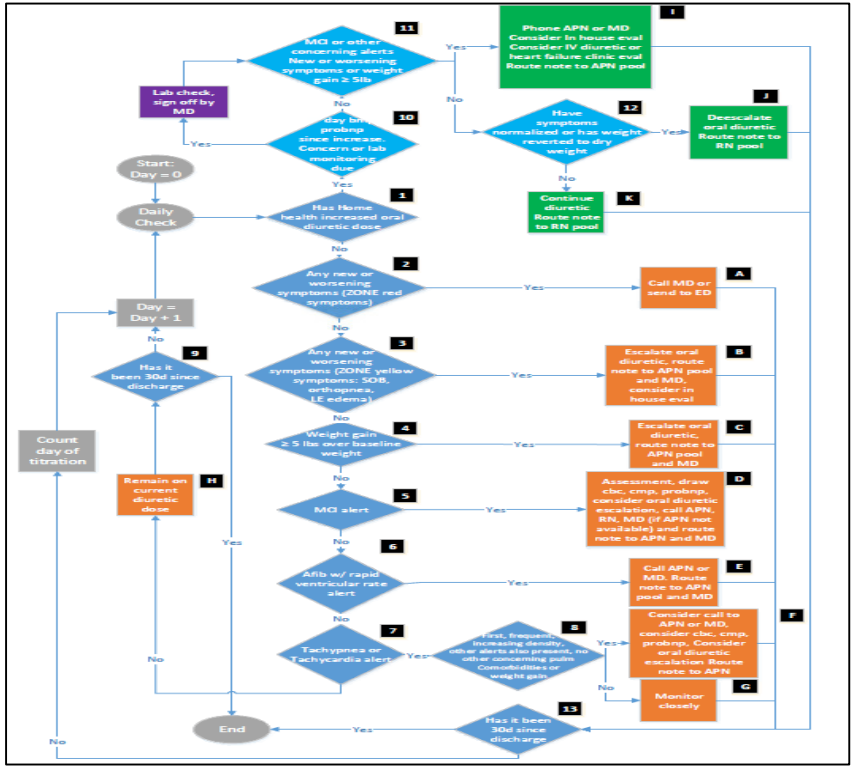
Web portal with physiologic, patient reported data and alerts

Home health nurse assessment

HF APP
HF attending

HF CRPM Protocol

- Patient-reported new/worsening symptoms
- Weight gain
- Key alerts: Afib, Tachycardia, Bradycardia, Tachnypea
- MCI alert: applies a personalized physiologic baseline established in the first 48 hours by studying the user's respiration, heart rate, sleep, and other parameters
- EHR structured notes



Research Problem

- Challenge: Limited ability to robustly estimate the workload of the care team and make appropriate staffing and operational decisions

- Approach: Use Discrete Event Simulation to mirror the real-world execution of CRPM in a virtual environment to
  - Estimate the care team's workload and its variability
  - Evaluate escalation patterns in the post-discharge period for patients at varying levels of readmission risk at discharge

Simulation Model

- Widely used to study workflow efficiency in diverse healthcare settings
- Arena simulation software (Rockwell Automation, Milwaukee, WI, student version 16.1)
- CAPE scores used to categorize patients into three distinct levels - High, Medium, & Low

Risk Category	Risk Criterion	Patient Composition
Low	<= 75th percentile	28%
Medium	> 75th and <= 90th percentile	32%
High	> 90th percentile	40%

- Utilize data from a pilot deployment with 44 patients to identify the composition of patients within each risk level and estimate the likelihood and frequency of alerts for each risk level
- Clinical guidance used to determine HHN tasks & activity times

Alert/Activity Type	Distribution Type
Nurse Consultations	Normal
MCI Alert	Lognormal

Results – Alert Summary

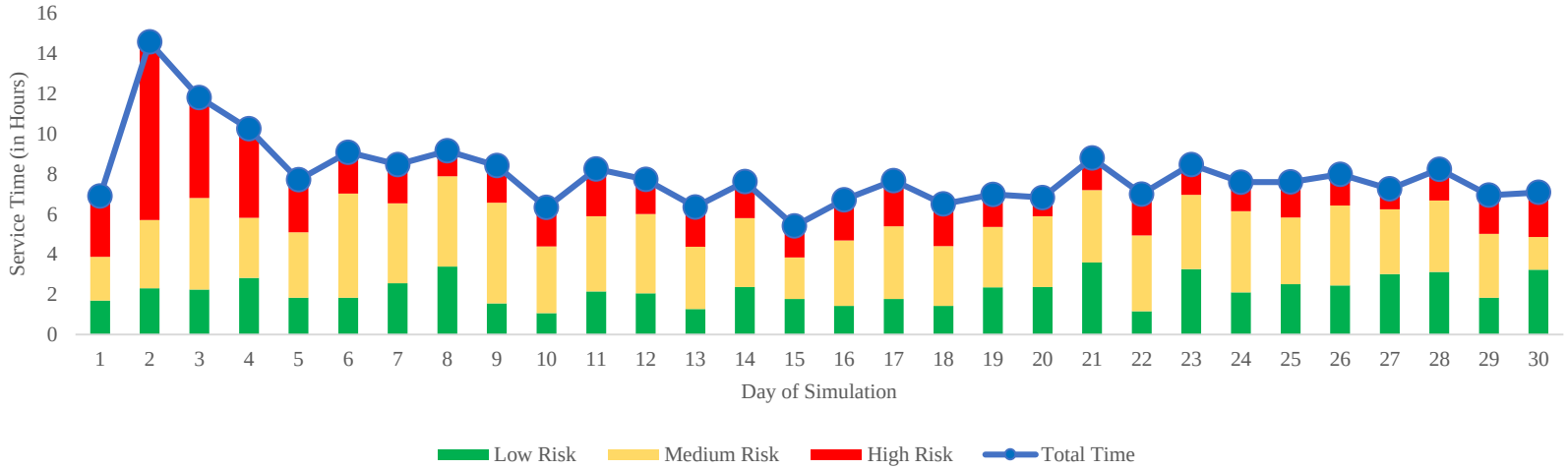
Alert Type	Frequency	Additional Time Spent/Patient to Address Alerts
Red Zone	4 patients	7 minutes
Yellow Zone	6 patients	15 minutes
MCI	4 patients	11 minutes
Escalation Pathway	10 patients	8 minutes

30-day monitoring period with 25 simulated patients

- Age: 40-85 years
- Weight: 100-250 lbs
- Initial titration dose of diuretic: 40-80 mg

- 4 red zone escalations – exit model
- 6 yellow zone escalations – increased diuretic
- 4 with MCI alerts – increased diuretic
- 10 in escalated care pathway, 4 readmitted – exit model

Results – Service Time Profile



Service Times by Risk Level & Variability in Home Health Nurses' Workload when monitoring 25 simulated CRPM patients at the same time

Limitations & Future Work

- Real-world usability is determined by the size and detail of the data sample used to instantiate DES model
- The limited sample used in this study may constrain the applicability and generalizability of the insights
- Future work will use data from a larger cohort of patients to instantiate and validate the model
- Ongoing extensions will test the design of prediction models embedded in the DES model using the new information produced each day

Conclusions

- Developed a scalable and generalizable approach using CRPM and DES
- Home healthcare teams and operational decision makers of healthcare systems can use to dynamically estimate staffing requirements and determine appropriate interventions that enable efficient care utilization
- Nurses/clinicians can use to anticipate and improve preparedness in the context of HF-related readmissions
- Researchers can leverage to generate new hypotheses on alert mechanisms, risk prediction indices and design of efficient post-discharge care pathways to potentially reduce risk of readmissions

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Thank you!

Questions?