CAPE: Clinical Analytics Prediction Engine

Session #310, February 15, 2019

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Conflict of Interest

Chad Konchak and Nirav Shah

Has no real or apparent conflicts of interest to report.

Agenda

- Current State of Predictive Modeling

- Vision of CAPE

- Modeling Performance

- EMR Integration and Prospective Modeling

- From predictive to prescriptive modeling and the learning health system

- Managing Change and Lessons Learned

Learning Objectives

Learning Objective 1

- Define, clearly, the problem with healthcare's current state of predictive modeling implementations and how they often fail to support clinical workflows and describe the CAPE framework for how to bring multiple predictive models into a single prescriptive engine

Learning Objective 2

- Describe an inventory of key patient outcomes to predict and how to achieve a high accuracy for prediction including both retrospective and prospective validation processes

Learning Objective 3

- Demonstrate the importance of tightly integrated predictive models into the EHR using real-time processing via the Predictive Model Markup Language (PMML) including implications for displaying the results and risk factors of a model to front-line clinicians

Learning Objective 4.

- Discuss the implications of a learning health system and how CAPE can help to achieve a better understanding of the impactability of patient populations based on multiple risk models and propose specific intervention bundles catered to the needs of that population

Learning Objective 5.

- Discuss the key cultural implications that an integrated predictive engine is able to facilitate and how it can enable the care team to improve patient outcomes while lowering costs

NorthShore
University HealthSystem

- 4 Hospitals
- 950 Beds
- 9000+ Employees
- 2700 Physician Medical Staff
- 900+ Employed Physician Medical Group
- 60,000 Annual Admissions
- 1.8 Million Annual Office Visits
- 125,000 Annual ED Visits
- $100M+ Research Institute
- HIMSS stage 7 Inpatient & Ambulatory
- H&HN Most Wired 15 years in a row
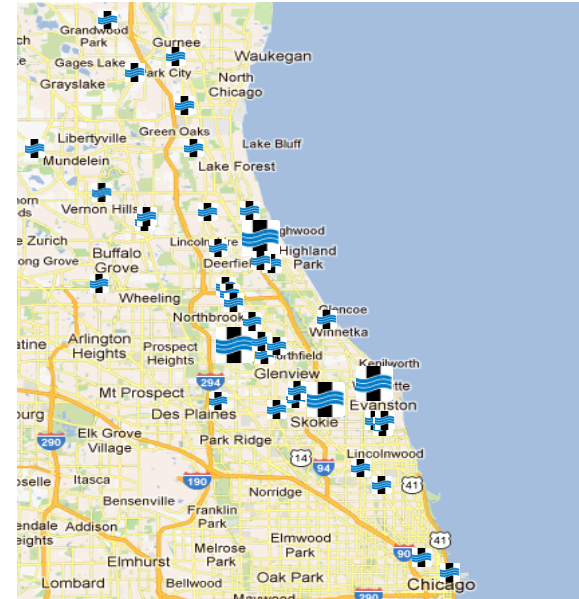
CAPE: Clinical Analytics Prediction Engine

Vision

Data enabled population healthcare delivery across the care continuum.

Paradigm Shift

1. Evolving from single siloed predictive models to a unifying risk profile

2. Population level enhanced and targeted interventions

3. Collaboratively designed, prioritized and coordinated care through Epic

Timeline
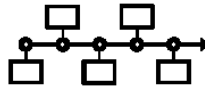
Phase I (Live September 2018): E-Cart*, Mortality and Readmission

WIP: Medical and Surgical Complications and Prospective Utilization

*A predictive model designed in partnership with University of Chicago based upon NorthShore patient population to detect patient deterioration. All other models described were developed by NSUHS

Our Patients

Low Mortality Risk

High Mortality Risk
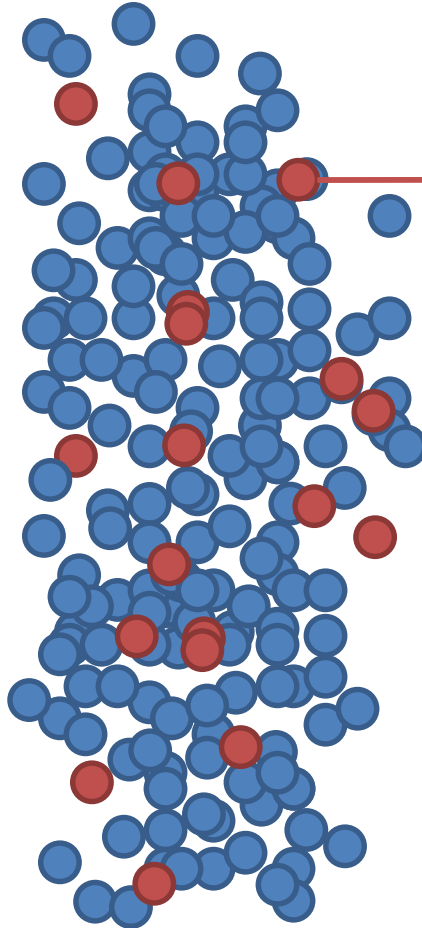
Mr. Smith is a 80 year old man with metastatic bile duct cancer with failure to thrive and progressive disease.
Pt is admitted for pneumonia

Predictive Modeling – Risk Stratification

Without predictive modeling

Homogenous interventions

With predictive modeling

$$Y = -8.833341 + (-0.212014) \times GENDER\_F$$
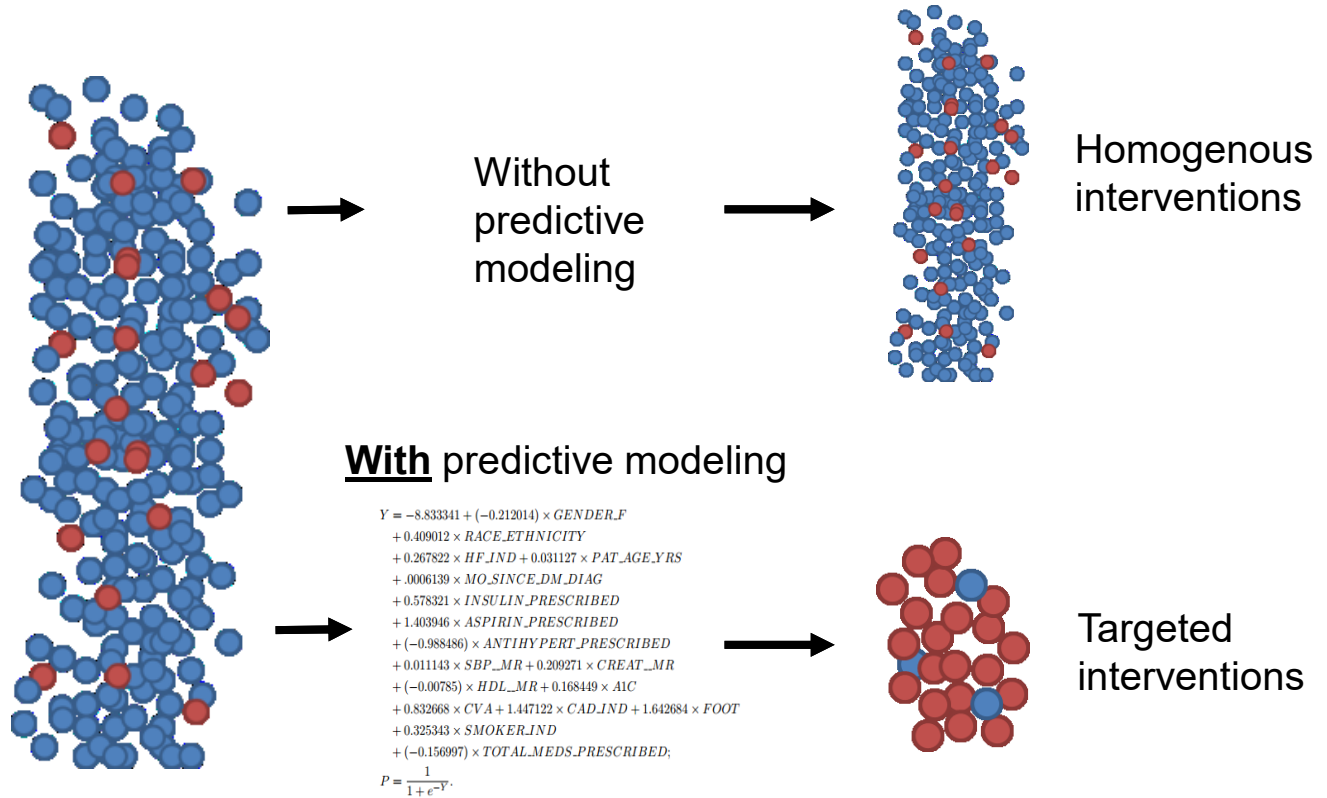$$+ 0.409012 \times RACE\_ETHNICITY$$
$$+ 0.267822 \times HF\_IND + 0.031127 \times PAT\_AGE\_YRS$$
$$+ .0006139 \times MO\_SINCE\_DM\_DIAG$$
$$+ 0.578321 \times INSULIN\_PRESCRIBED$$
$$+ 1.403946 \times ASPIRIN\_PRESCRIBED$$
$$+ (-0.988486) \times ANTIHYPERT\_PRESCRIBED$$
$$+ 0.011143 \times SBP\_MR + 0.209271 \times CREAT\_MR$$
$$+ (-0.00785) \times HDL\_MR + 0.168449 \times A1C$$
$$+ 0.832668 \times CVA + 1.447122 \times CAD\_IND + 1.642684 \times FOOT$$
$$+ 0.325343 \times SMOKER\_IND$$
$$+ (-0.156997) \times TOTAL\_MEDS\_PRESCRIBED;$$
$$P = \frac{1}{1 + e^{-Y}}.$$

Targeted interventions

The Potential of CAPE for Mr. Smith

Without **CAPE**

Transfer to the ICU with respiratory failure and sepsis. Mr. Smith requires intubation and prolonged ICU stay.

The Potential of **CAPE**

eCART warning leads to early intervention allowing patient to stay on the floor. **In-hospital mortality** identifies patient, prompting revisiting advanced care planning and revising goals of care. A prolonged ICU stay is avoided.

How is the Paradigm Shifting?

Alert — High Readmission Risk!

Alert — High Mortality Risk!

Alert — High eCART Risk! OK
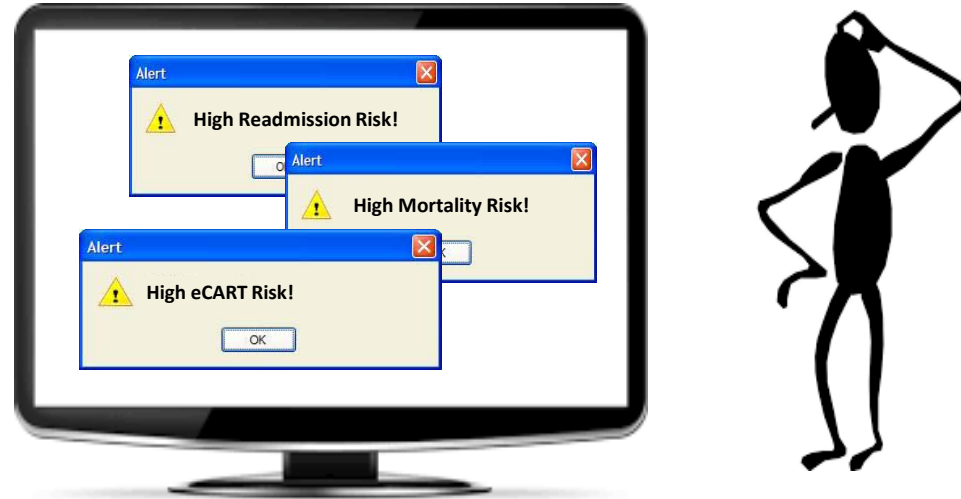
1. What needs to be done?
2. Who needs to do the intervention?
3. How fast does the intervention need to be performed?

Deploying Interventions

1 Individual predictive models

2 CAPE Integration

3 Interventions Identified

4 Interventions triaged Across care team

Ecart

Mortality

Readmission

CAPE

High Priority Patient!

In Next Hour
- [ ] ICU Evaluation
- [ ] Q2h Vitals

Hospitalist

Floor Nurse

Within 24 hours
- [ ] ACP & Goals of Care

Chaplain

Before Discharge
- [ ] Med to Bed

Pharmacist

After Discharge
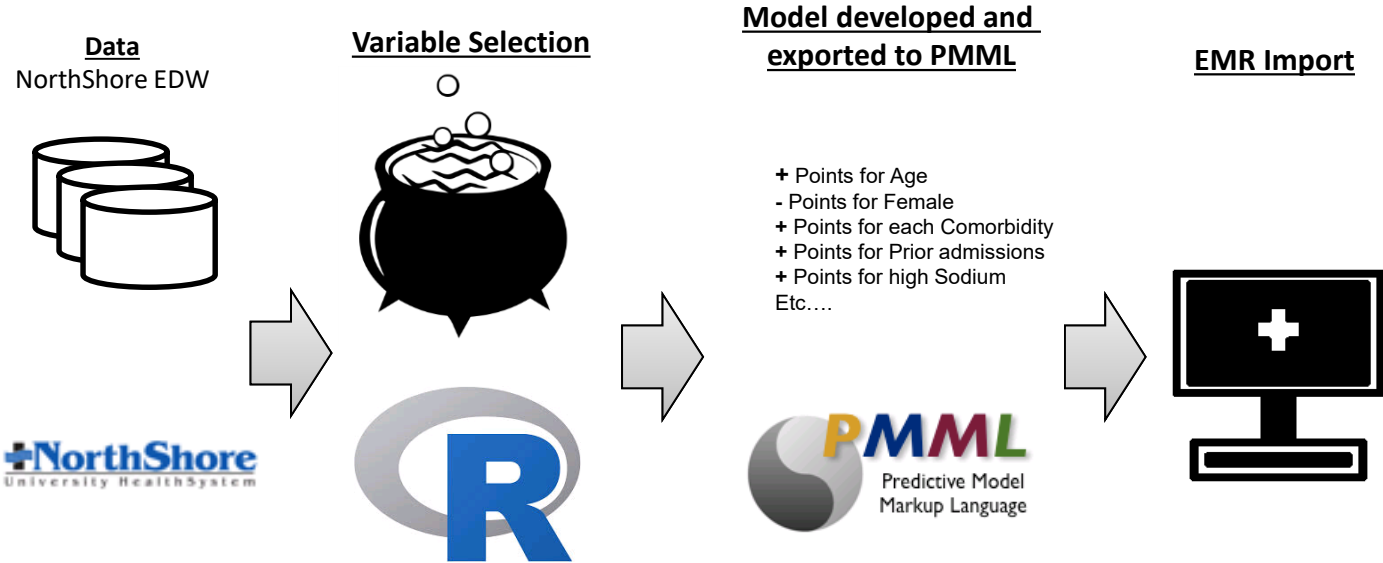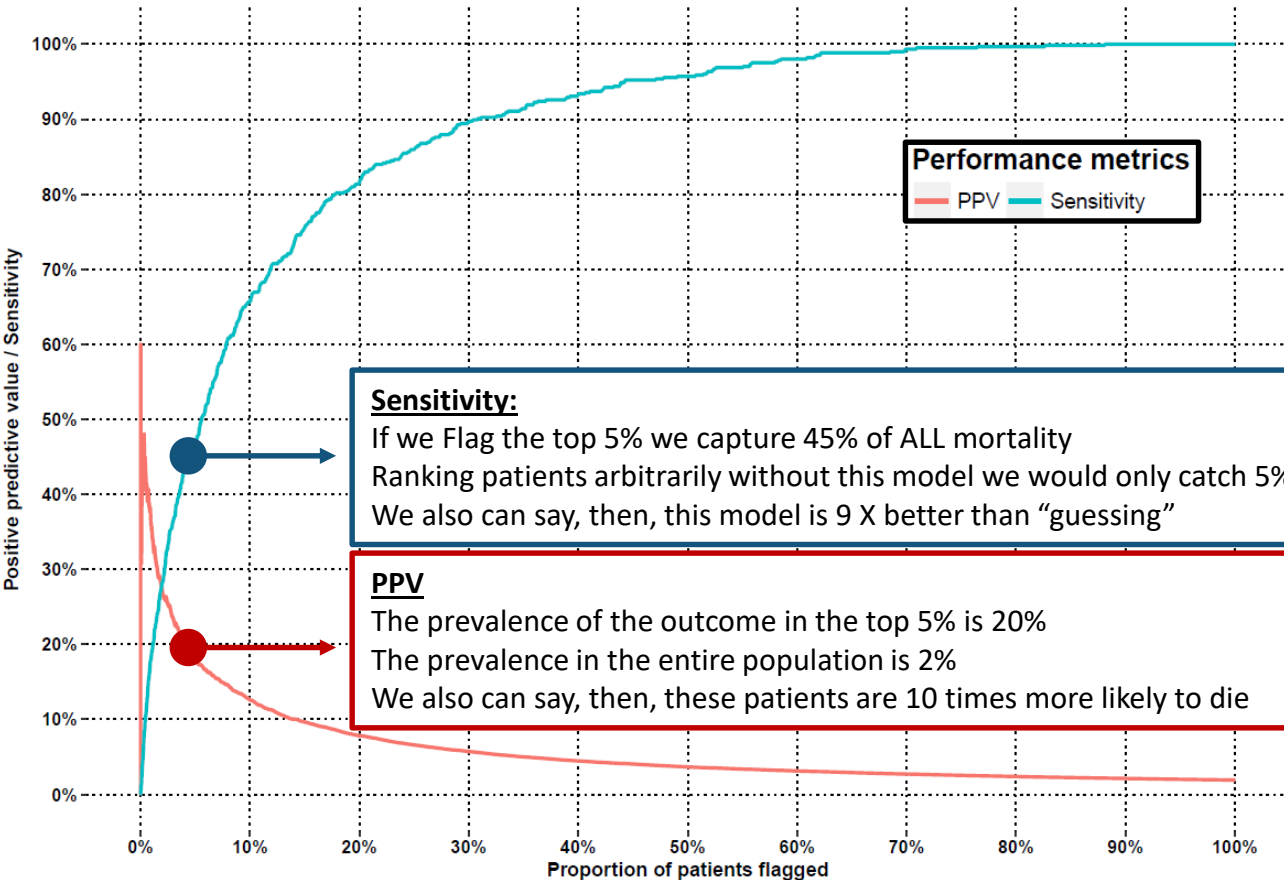- [ ] PCP Appointment outreach

PCP

CAPE will take all risk scores into account, identify patients with a care gap, present checklists of interventions to the right caregivers and assign a priority of how quickly the task needs to be performed all within EPIC

Building a Predictive Model – In The EMR

Data
NorthShore EDW

Variable Selection

Model developed and exported to PMML

EMR Import

+ Points for Age
- Points for Female
+ Points for each Comorbidity
+ Points for Prior admissions
+ Points for high Sodium
Etc….

NorthShore
University HealthSystem

R

PMML
Predictive Model
Markup Language

Train, test, and evaluate performance

CAPE model validation for dates between 2012−01−01 00:15:00 and 2017−04−30 22:49:00

Performance metrics
PPV   Sensitivity

Sensitivity:
If we Flag the top 5% we capture 45% of ALL mortality
Ranking patients arbitrarily without this model we would only catch 5%
We also can say, then, this model is 9 X better than "guessing"

PPV
The prevalence of the outcome in the top 5% is 20%
The prevalence in the entire population is 2%
We also can say, then, these patients are 10 times more likely to die

Positive predictive value / Sensitivity (y-axis)
Proportion of patients flagged (x-axis)

AUC: 0.9

The AUC takes into account how often your model "got it right":

An AUC of 0.5 = flipping a coin
You want to be above at least .65 (but as usual, it depends)
An AUC of 0.9 is really, really good!

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Model performance[1] – Phase I

Predictive model	AUC	PPV[2]	Sensitivity	Lift
eCART cardiac	0.75	0.08	0.45	7.5
In-hospital mortality	0.89	0.13	0.66	6.6
30-day out-of-hospital mortality	0.85	0.16	0.45	4.5
90-day out-of-hospital mortality	0.85	0.26	0.42	4.2
180-day out-of-hospital mortality	0.85	0.36	0.38	3.8
30-day readmission	0.72	0.30	0.26	2.6

[1]Model performance is likely to change after final Epic build adjustments
[2]ePPV, sensitivity and Lift are measured at the 10th %-le of the population
[3]eCART performance is based on Feb. 2017 testing data

Prospective Validation

- Typical model validation stops after retrospective validation
- For CAPE, we had a "soft go-live" and monitored the models in live production
- Evaluated model performance at two time periods
    - 4 Hours upon ED Arrival
    - 24 Hours after floor
- Operational decisions and model sign-off based on 4hr ED Model
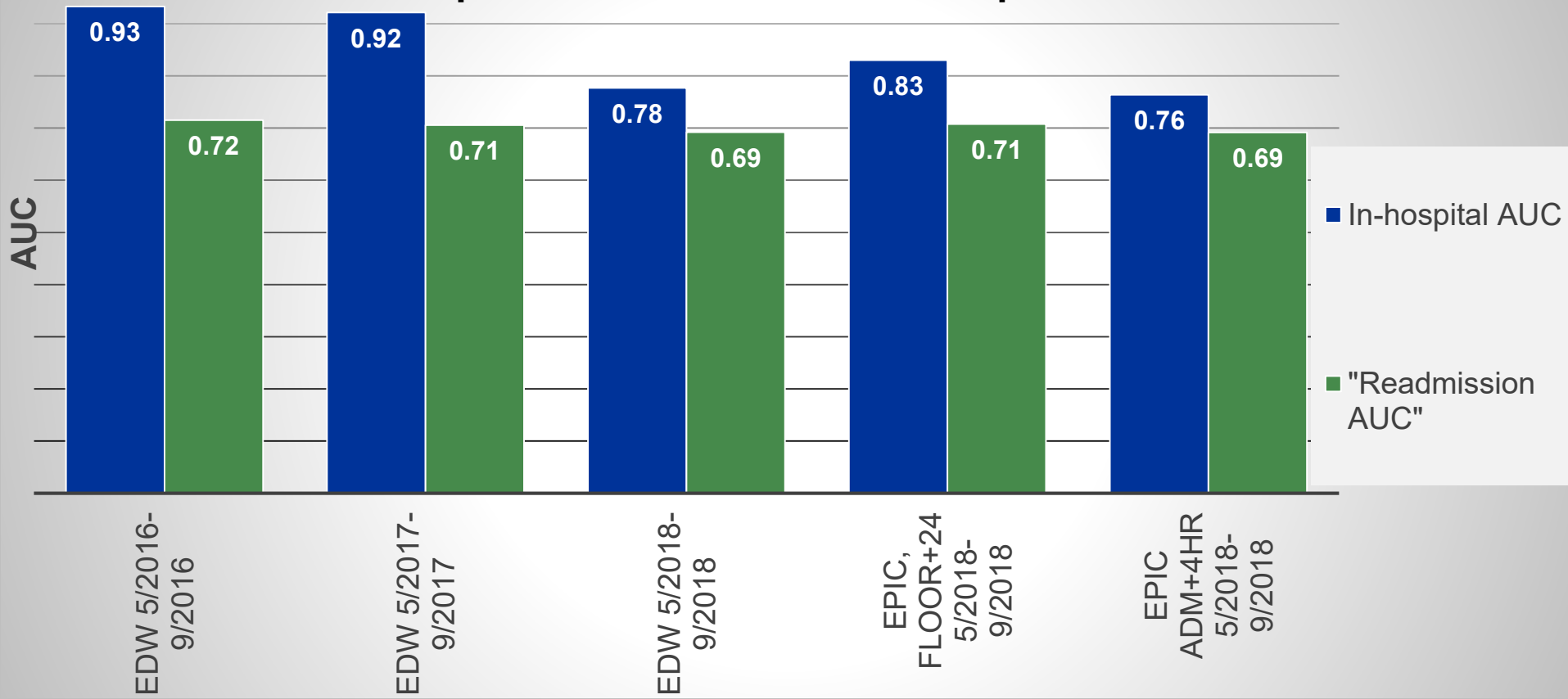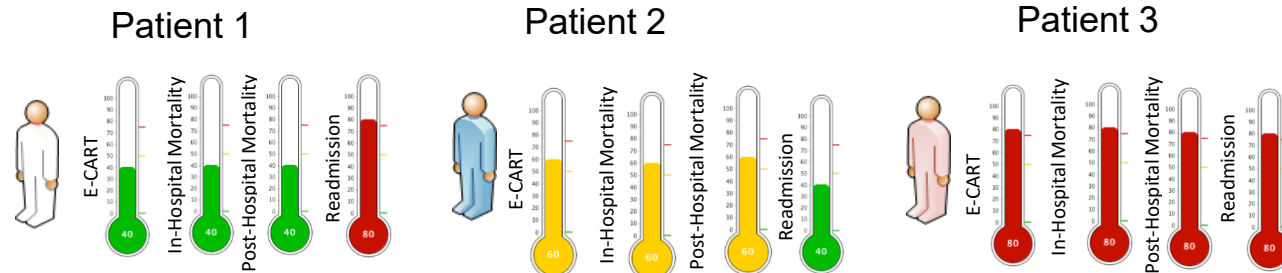
Integrate Each Model into Patient Risk Profiles

- In the "Old Days" we would be done
- With CAPE, we need to do this for ALL our outcomes
  1. E-CART Risk Score
  2. In Hospital Mortality Risk Score
  3. Post Hospital Mortality Risk Score
  4. Readmission Risk Score

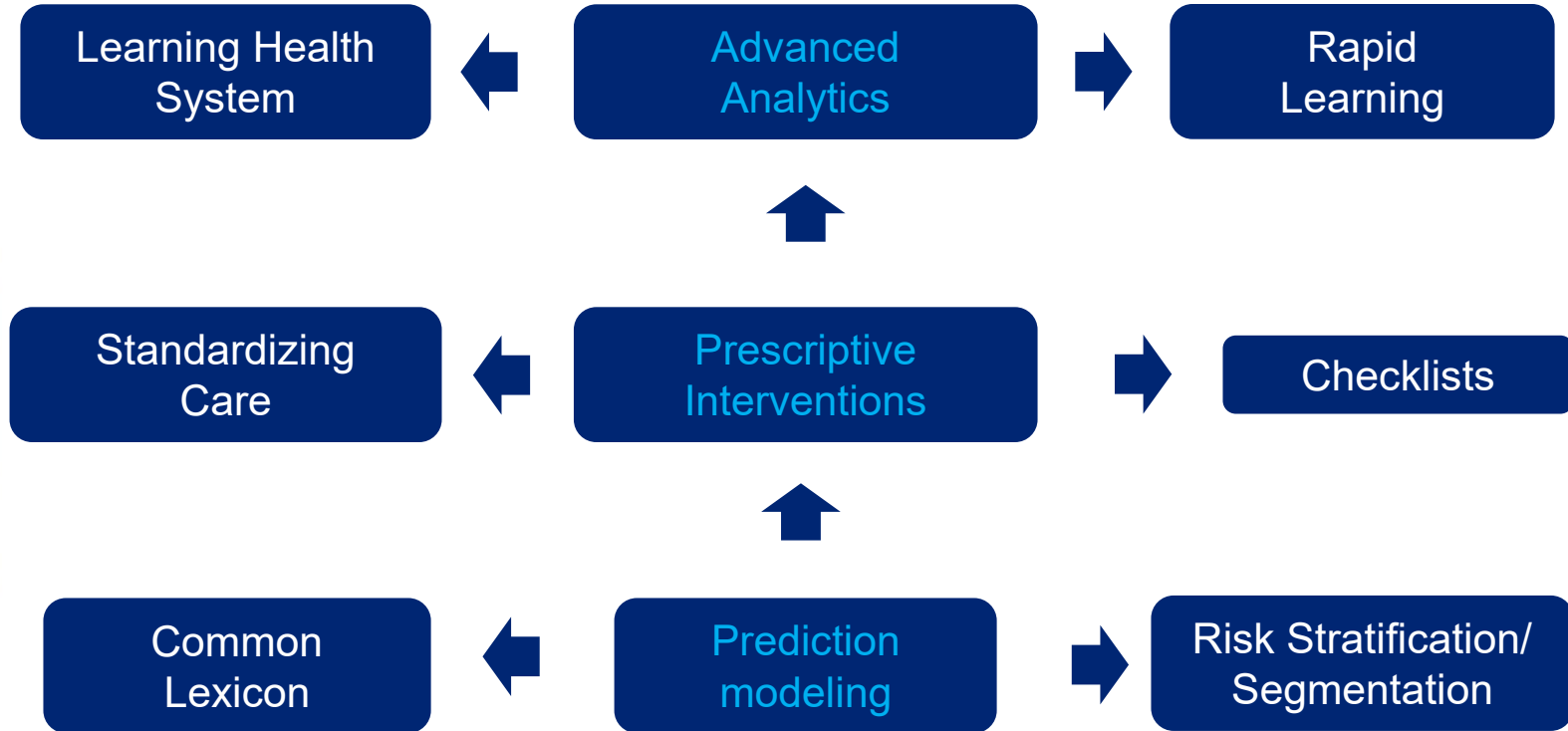Now, *every* patient has a different risk score for 4 outcomes

Patient 1   Patient 2   Patient 3

And there are a LOT of different-looking types of patients

Prescriptive Interventions Based on Risk

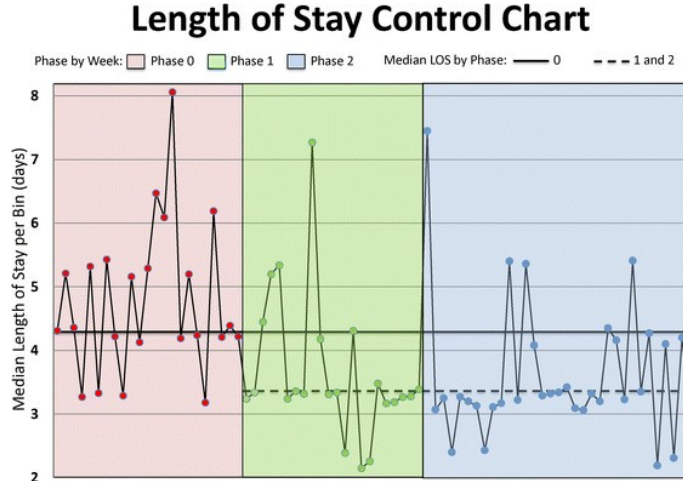| Risk Identified	Priority	Care Provider	Intervention
E-cart Red	<2 hours	Physician	Assess, Code Status, ICU
E-cart Yellow	<30 mins	Nurse	q2hVitals x 8h, lactic acid, accompanied off unit
Mortality	TBD	SW/Chaplain	Identify ACP, PCP agrees w/ GOC? GOC and document

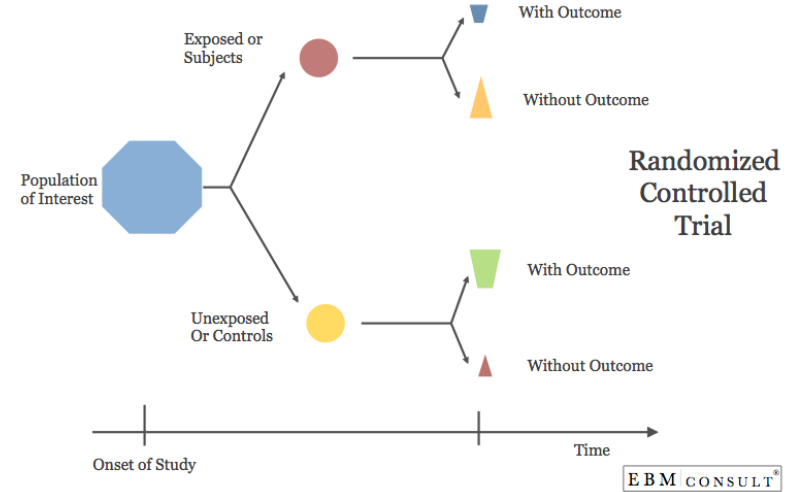| Risk Identified	Priority	Care Provider	Intervention
Readmission	PTD	Pharmacist/ Primary MD	Med to Bed
Readmission	Within 48h post discharge	CT office	Patient touchpoint to ensure appropriate post discharge care
Readmission	PTD	CM	High risk CM enrollment

Why are we doing this?

Learning Health System	←	Advanced Analytics	→	Rapid Learning

↑

Standardizing Care	←	Prescriptive Interventions	→	Checklists

↑

Common Lexicon	←	Prediction modeling	→	Risk Stratification/ Segmentation

How do we know if we are making a difference?

Length of Stay Control Chart

Knowledge captured
as byproduct of care
delivery experience

Randomized
Controlled
Trial

Methodological rigor
Effect size

Advanced Analytics – Pragmatic Study Design

Intervention

High risk of outcome of interest

Provider sees alert and completes task

Provider does not see alert. Task not completed
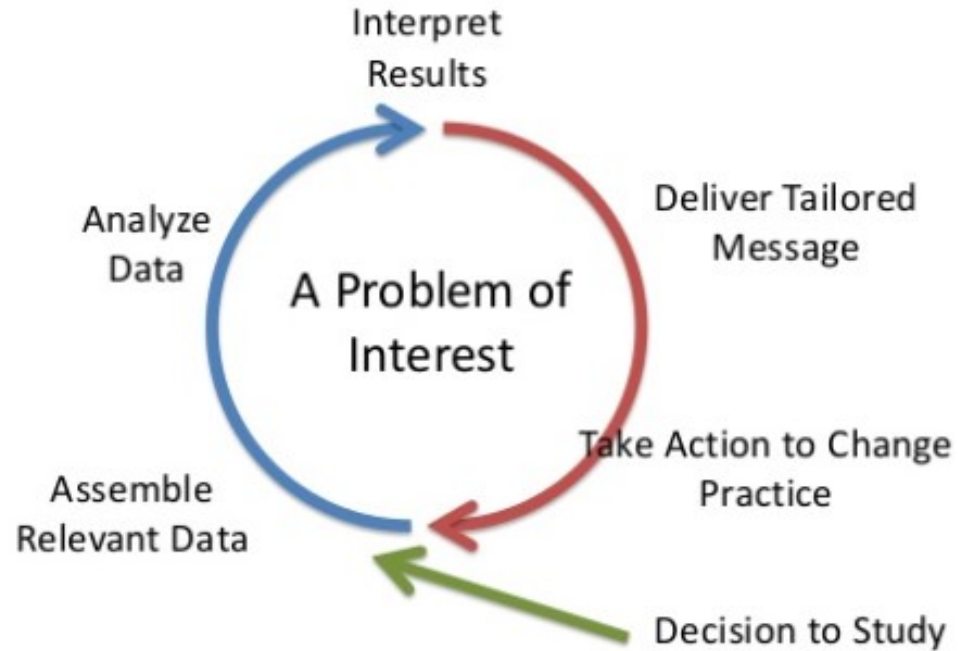
Control
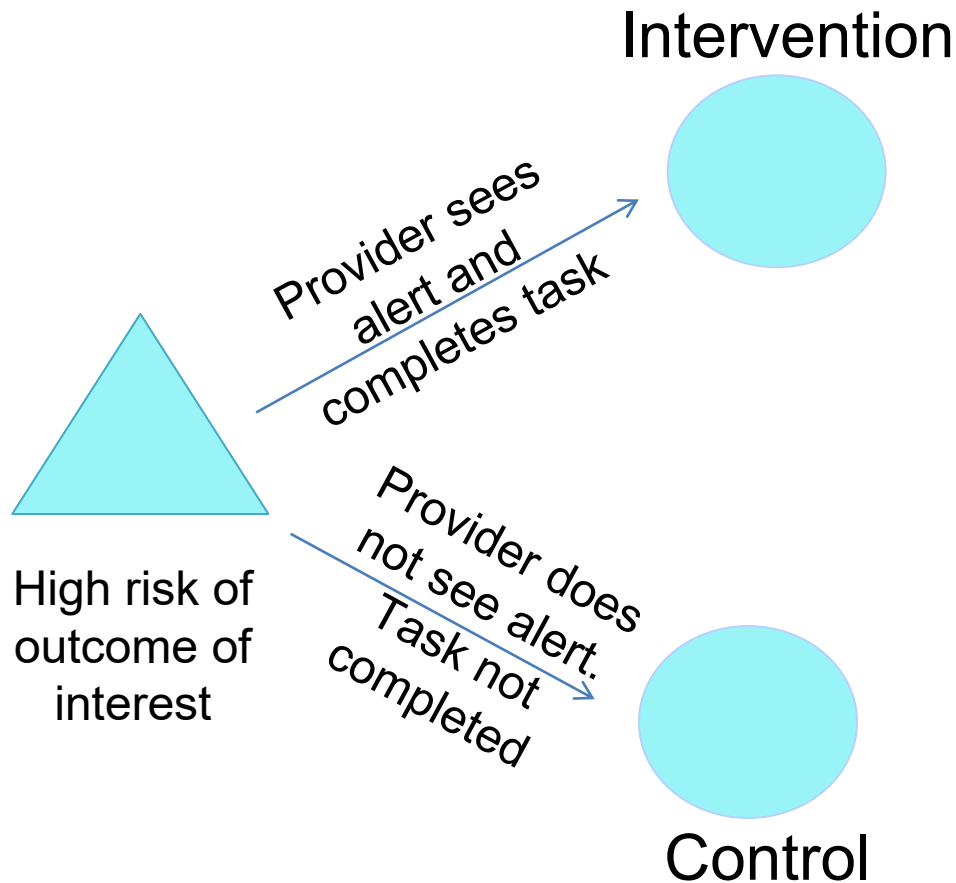
Analysis design:
- Normal patient care
- Randomization
- Double blind
- No withholding of care
- All built into electronic medical record
- Requires IRB approval

Learning Health System

The development of a continuously learning health system in which science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience

Learning Health System

Interpret Results

Deliver Tailored Message

Analyze Data

A Problem of Interest

Take Action to Change Practice
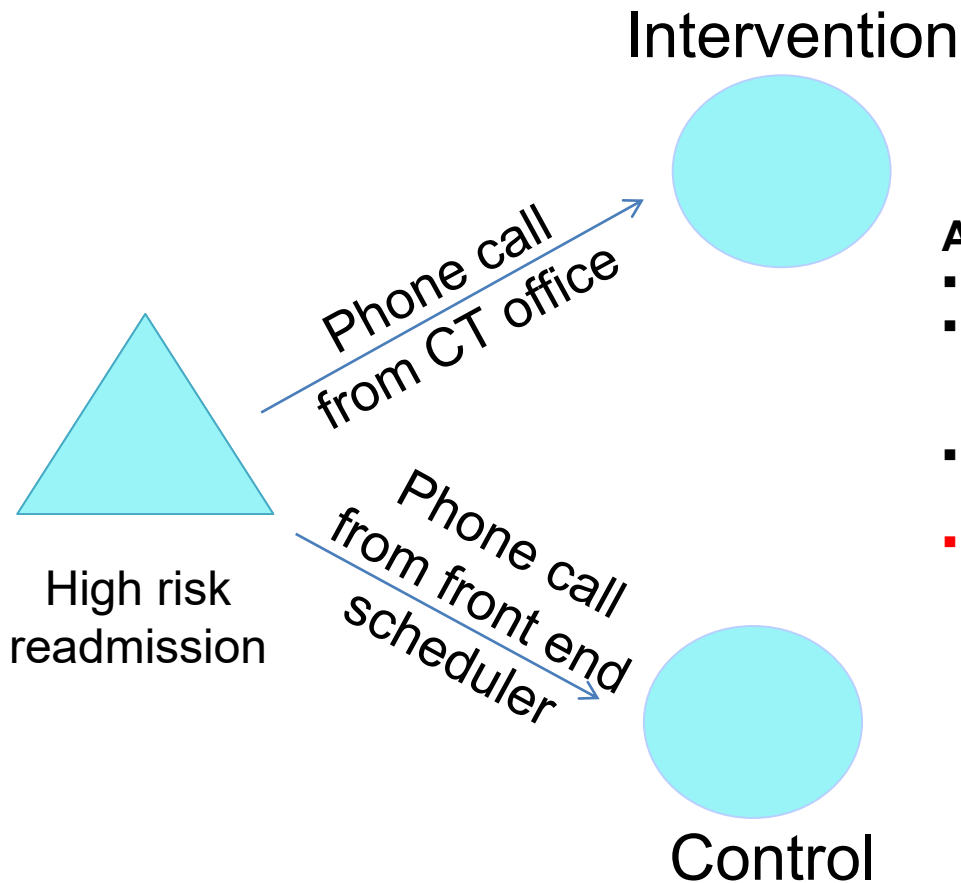
Assemble Relevant Data

Decision to Study

Rubin, AMIA 2016

Early Results - eCart

- Cardiac Arrest Model (eCart)

- Scores >95th percentile were flagged red or highest risk. Scores between 85-95th percentile were flagged yellow, or intermediate risk

- ICU transfer was strongly urged for new red scores, *but the discretion of the treating physician could overrule.* Yellow score patients had increased frequency of vital signs on the floor.

- Outcomes:

  - Red score patients transferred to the ICU had a lower mortality when compared with controls (18.4 vs 32.5%; X^2 p=0.0004)

  - Time to ICU transfer decreased from 6.5 (IQR 21.8) to 2.2 (IQR 4.6) hrs p=0.0001

Advanced Analytics – Post Discharge Phone Call

Intervention

Control

High risk readmission

Phone call from CT office

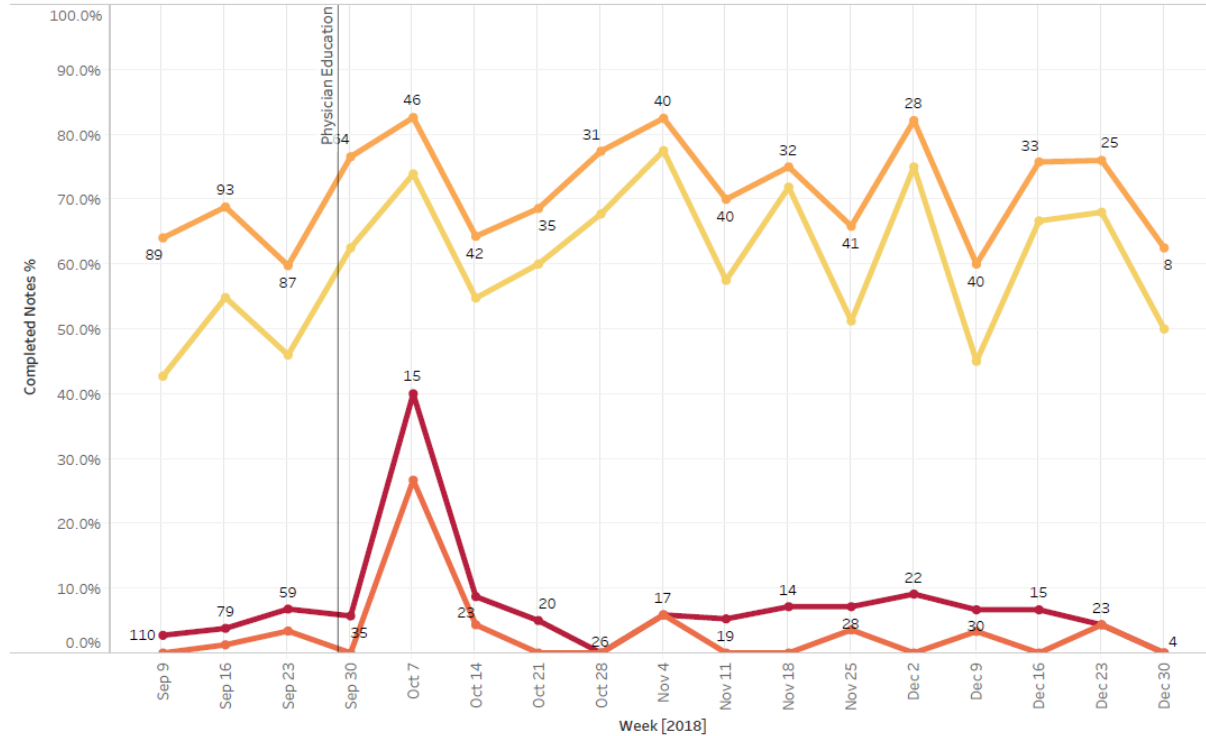Phone call from front end scheduler

Analysis design:
- 6 week randomization
- 30 high risk patients daily with FTE to perform 20 interventions max per day
- 900 Patients, 600 Intervention, 300 Control
- Primary outcome: effect on all cause readmission

Compliance Rate

Note Completion Rates

Numerator 1: Notes Written
Numerator 2: Notes Written within target time of 2 Hrs of BPA
Denominator: Admissions with at least one eCART BPA

Number labels are count of Admissions for that week, assigned to the first day of the week.
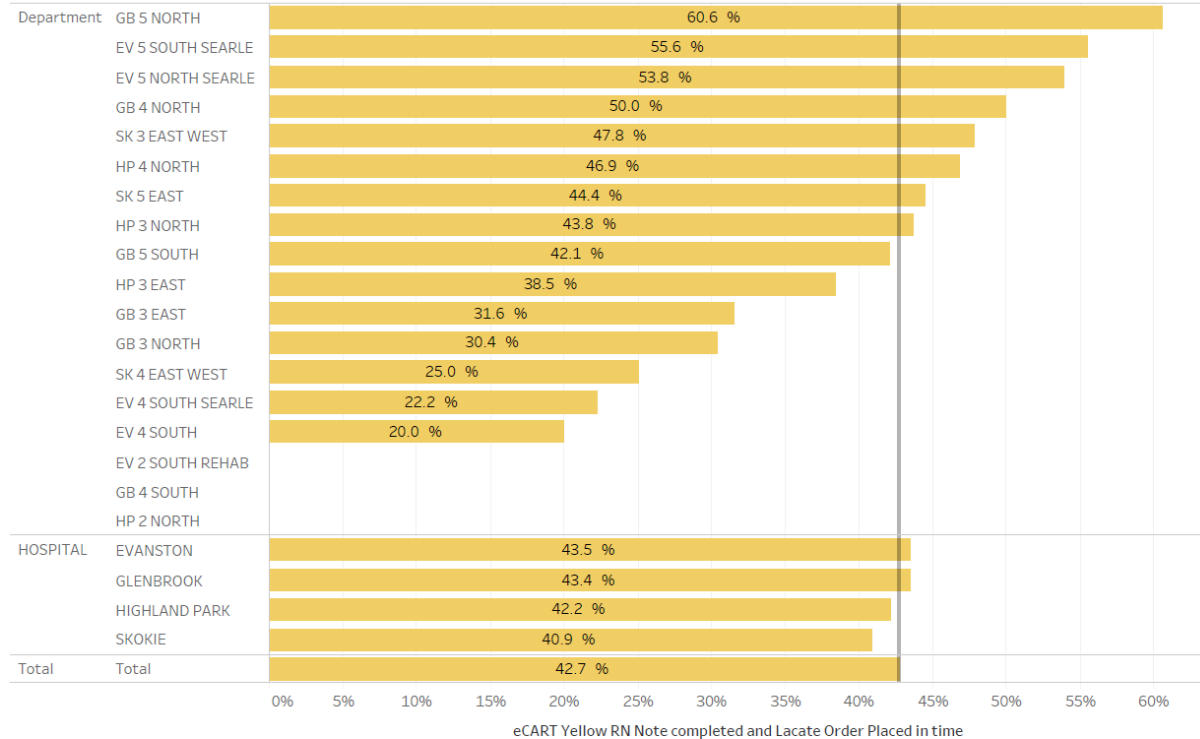
eCART Note Completion Rates
- Yellow, Note Completion
- Yellow, Note Completion w/in 2Hrs
- Red, Note Completion
- Red, Note Completion w/in 2Hrs

Compliance Rate

eCART Yellow Lactate Order Followup Rate

Department		Rate
Department	GB 5 NORTH	60.6 %
	EV 5 SOUTH SEARLE	55.6 %
	EV 5 NORTH SEARLE	53.8 %
	GB 4 NORTH	50.0 %
	SK 3 EAST WEST	47.8 %
	HP 4 NORTH	46.9 %
	SK 5 EAST	44.4 %
	HP 3 NORTH	43.8 %
	GB 5 SOUTH	42.1 %
	HP 3 EAST	38.5 %
	GB 3 EAST	31.6 %
	GB 3 NORTH	30.4 %
	SK 4 EAST WEST	25.0 %
	EV 4 SOUTH SEARLE	22.2 %
	EV 4 SOUTH	20.0 %
	EV 2 SOUTH REHAB	
	GB 4 SOUTH	
	HP 2 NORTH	
HOSPITAL	EVANSTON	43.5 %
	GLENBROOK	43.4 %
	HIGHLAND PARK	42.2 %
	SKOKIE	40.9 %
Total	Total	42.7 %

eCART Yellow RN Note completed and Lacate Order Placed in time

Numerator: Lactate orders placed within 2 hrs of complete "Acknowledge Yes" RN Note written, or an order has already been in place 24 hours prior to the note being written

Denominator: eCART Yellow RN Note written with "Acknowledge YES" selected

#HIMSS19

Lessons Learned – Compliance

- Understand key process metrics
- Resistance to change and standardization MD >> RN
- Thoughtful about workflows and user interface
- Steady and continuous messaging and education
- Data driven process employing mixed methods
- Quick and direct feedback loop

Culture and Change Management

- Executive Support & Alignment with goals across health system
- Clear vision & ability to articulate this vision – CAPE Tour
- Data and Tech heavy project – Need to invest in analytics/informatics
- Clear governance structure
- Persistence
- Need early quick wins
- Celebrate success

6 Tips On Driving Innovation – Even If You Think Your Boss Will Say No

- Innovation isn't impossible in large organizations – but you'll need determination
- Being creative is great, but innovators turn creativity into output
- De–risk your idea as far as you can
- Learn collaboration – it's not the same as teamwork
- Get out of the office
- Don't expect everyone to say yes straightaway

17,382 views | Feb 25, 2014, 09:43am

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Questions?

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