CONCERN

COMMUNICATING NARRATIVE CONCERNS ENTERED BY RNS

This project is supported by: National Institute of Nursing Research (NINR): 1R01NR016941-01 Sarah Rossetti and Kenrick Cato MPIs

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Overview

- Background: What is CONCERN?
- Study Specific Aims
-  Ongoing Informatics/Data Science Work
- Discussion/Conclusions
- Next Steps

Introduction to the Patient Safety Issue

- Many inpatient deaths are preventable
  - 130,000-200,000 inpatient deaths from cardiac arrest and sepsis (Merchant et al., 2011; Liu et al., 2014)
- Nurses detect subtle indicators of patient deterioration and increase surveillance in response
  - Document concern for risky patient states in flowsheet comments before vital sign changes
- Difference between the physician's expectations for physiological changes and the nurse's observations
- Sub-optimal interdisciplinary communication

Nursing documentation patterns and content useful to predict deterioration and mortality in inpatient settings

EHR Metadata Patterns As Signals Of Clinical Concern

- Focusing only on EHR data values will miss healthcare processes and nursing interventions activated far before a patient's vital signs are abnormal
- Approach can shift how we understand and leverage clinical observational skills and clinician entered data within a patient's chart

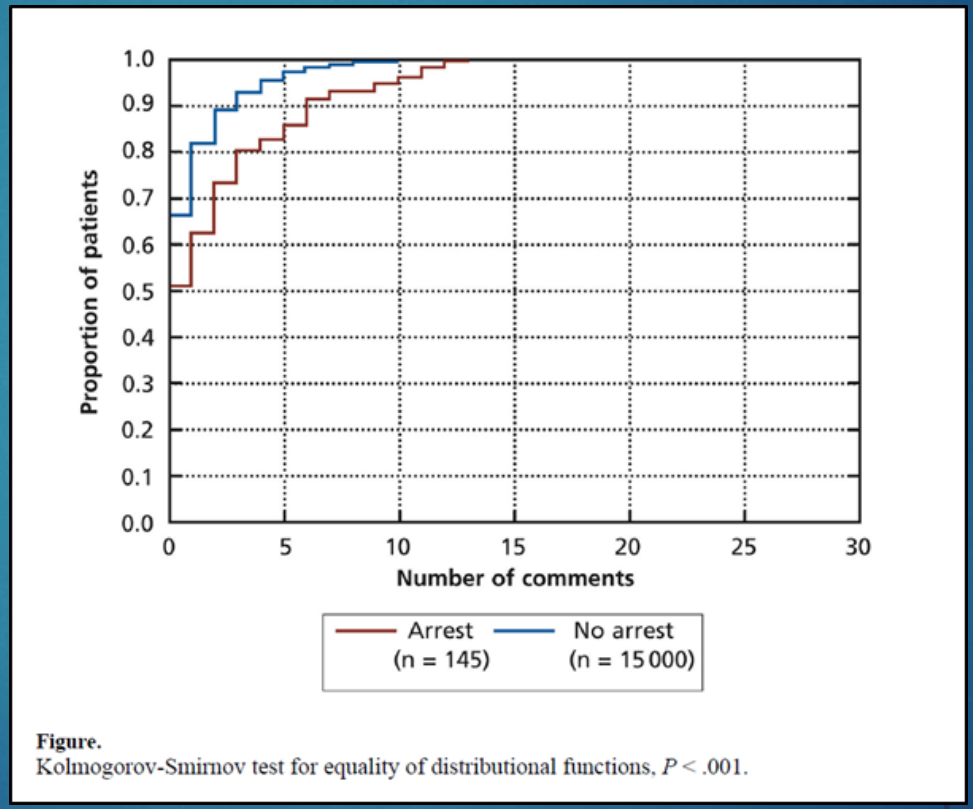


Figure.
Kolmogorov-Smirnov test for equality of distributional functions, $P < .001$.

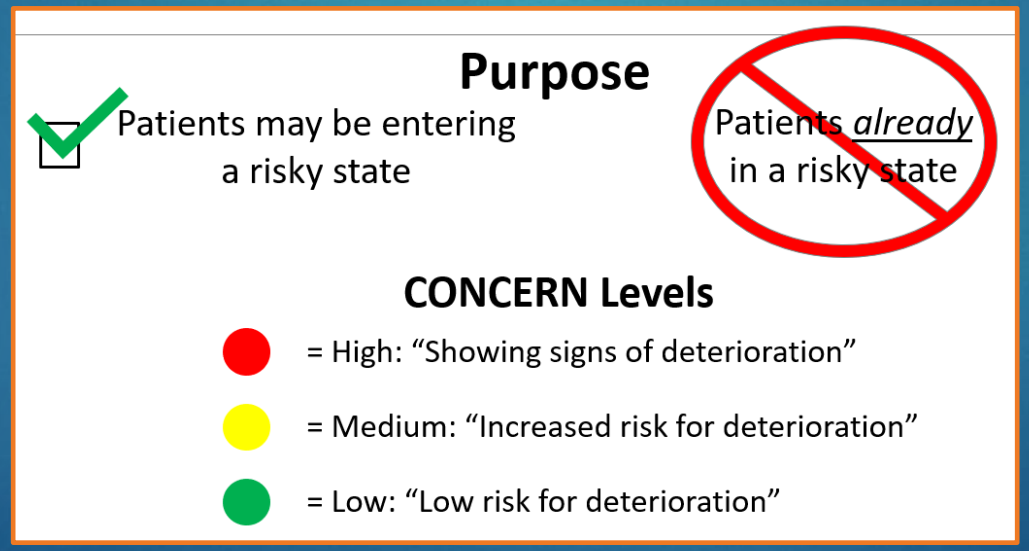
The act of documenting a free-text comment or other optional data in a flowsheet row

Information that the nurse likely determined an event or observation was clinically significant enough to record

Rossetti SC, Knaplund C, Albers D, Dykes PC, Kang MJ, Korach TZ, Zhou L, Schnock K, Garcia J, Schwartz J, Fu LH. Healthcare Process Modeling to Phenotype Clinician Behaviors for Exploiting the Signal Gain of Clinical Expertise (HPM-ExpertSignals): Development and evaluation of a conceptual framework. Journal of the American Medical Informatics Association. 2021 Jun;28(6):1242-5

What is CONCERN?

- Early warning system (EWS) for patient deterioration based on nursing documentation patterns or "signals".
- Detects the nurses' expert clinical judgment when it perceives changes in a patient's clinical state.
- Alerts earlier than other EWSs, because these subtle patient changes usually occur well before physiological alterations in the patient.
- Leverages existing documentation, preventing increases to documentation burden.

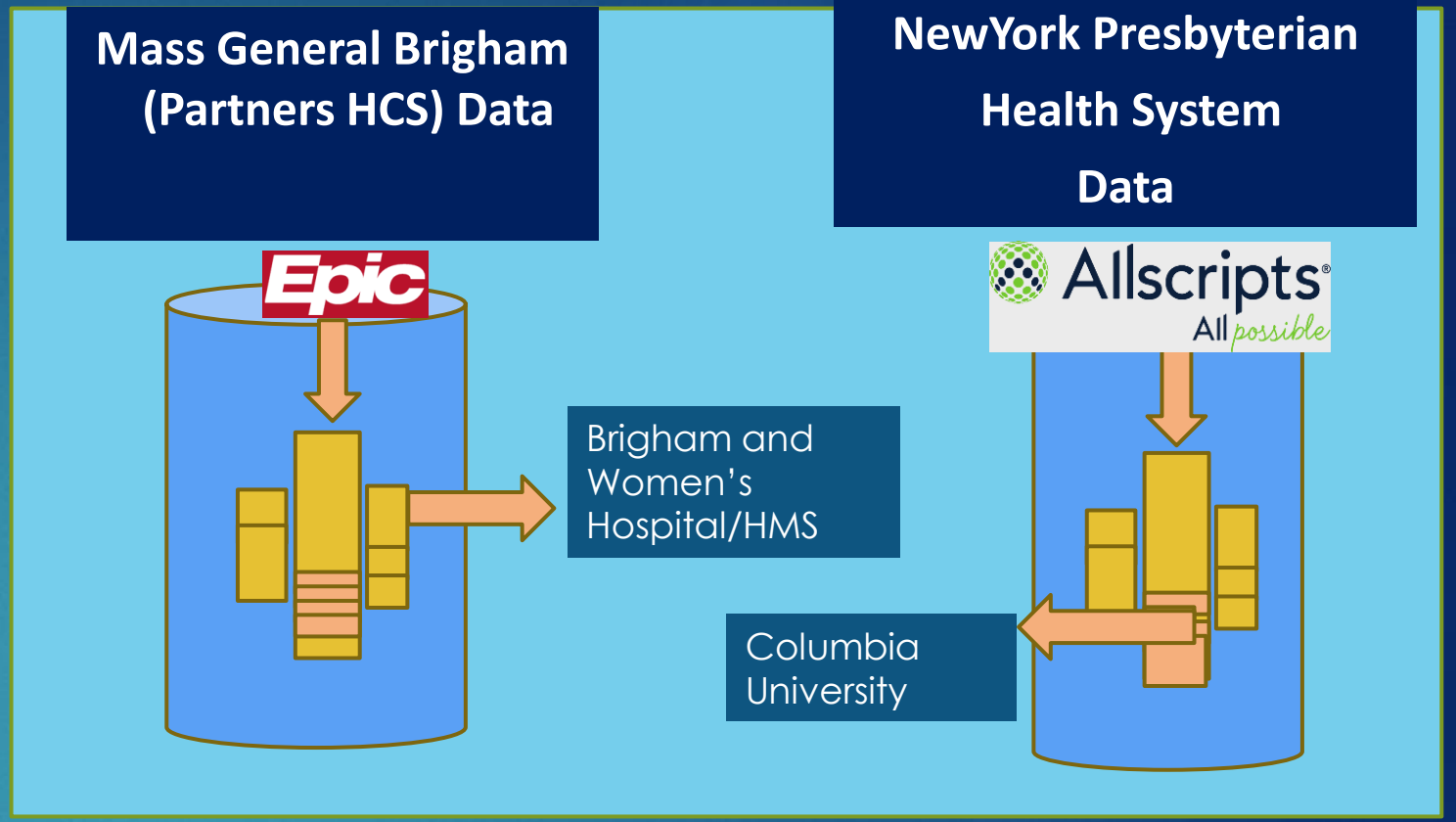


COmmunicating **N**arrative **C**oncerns **E**ntered by **RN**s

CONCERN Specific Aims

- **Aim 1**. Perform analytics of existing nursing data and documentation patterns to confirm predictive factors and notification thresholds for patients at risk of adverse outcomes in the hospital
  - Natural Language Processing (NLP)
  - Machine Learning
  - Predictive analytics
- **Aim 2**. User-centered design and testing of CONCERN SMART App
  - Prototype development and simulation testing
- **Aim 3**. Implementation and evaluation of the impact of the CONCERN SMART App on patient outcomes
  - **Primary outcomes:** in-hospital mortality and length of stay
  - **Secondary outcomes:** cardiac arrest, unanticipated transfers to the intensive care unit, and 30-day hospital readmission rates.
  - **Hypothesis:** CONCERN SMART App will be associated with decreased in-patient mortality, length of stay, and 30-day hospital readmission rates across two hospital systems compared to current state.

CONCERN Goal: Expose predictive data from clinical documentation to physicians and nurses to increase care team situational awareness of at risk patients to decrease preventable adverse outcomes



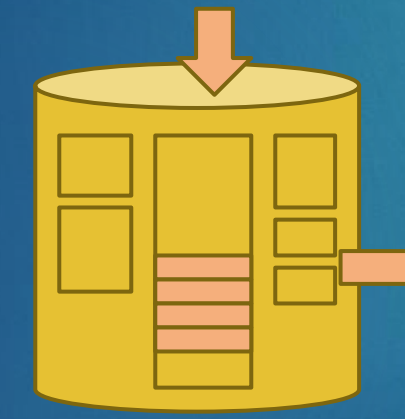
CONCERN DATA

HARMONIZATION, ACQUISITION AND VALIDATION

2+ years of work to harmonize data and build CONCERN database…
…now have a resource for future projects

NewYork Presbyterian Health System Data

Allscripts
All possible

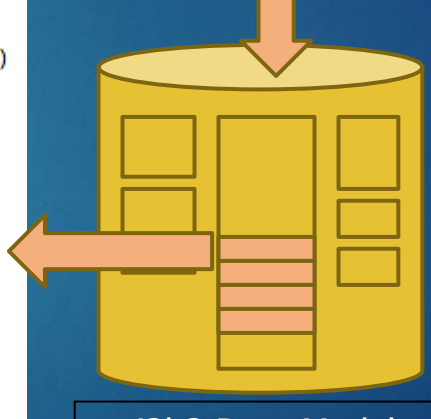


i2b2 Data Model

- CONCERN Flowsheets v2
  - Assessment (IP SIMPLE ASSESSMENT)
  - Audit C/Tobacco (PHS AUDIT C NAV)
  - Braden Scale Assessment (PHS IP BRADEN SCORE/SKIN NAV)
  - Complex Assessment (IP COMPLEX ASSESSMENT)
  - Daily Cares/Safety (IP DAILY CARES/SAFETY)
  - Intake/Output (IP INTAKE/OUTPUT)
  - Intra Procedure Sedation (INTRA OP SEDATION DOCUMENTATION)
  - IV Line Assessment (IP IV ASSESSMENT)
  - Occupational Performance (T PHS IP OT OCCUPATIONAL PERFORMANCE NAV)
  - Psycho/Social/Spiritual (PHS PSYCHOSOCIAL INA NAV)
  - PT Ranking (PHS IP PT RANKING)
  - QIDS-C (QUICK INVENTORY OF DEPRESSIVE SYMPTOMATOLOGY)
  - Screenings (SCREENINGS)
  - Vital Signs (IP VITALS SIMPLE)
  - Vital Signs Complex (IP VITALS ICU)
- CONCERN Notes
  - Assessment & Plan Note
  - Family Meeting
  - H&P
  - Nursing Note
  - Nursing Summary
  - Plan of Care
  - Procedures
  - Progress Notes
  - Rapid Response Documentation
  - Significant Event
  - Transfer / Sign Off Note
  - Transfer of Care

Mass General Brigham Data

Epic



i2b2 Data Model

Harmonizing nurse data at the *concept level*

NYP Study Location
AF2W
M5GS
M5GN
M7HS
M7GS
M8MA
M6GN
AF2E
M8HN
M8HS
M9GS
AR2W
H5CC
M5CC
AICU
H5CT

CONCERN Location (i2b2)
ACE
CARDACU
CTSURGACU
IDACU
MEDACU
MEDSURGACU
NEUROACU
ORTHOACU
CCU
COMMICU
CTICU
MICU
NEUROICU
SICU
CARDSDU
MEDSURGSDU
NEUROSDU

PHS Study Location
10030010009
10030010514
10030010525
10020010625
10050020023
10050020025
10010010011
10030010004
10030010007
10030010311
10030010312
10030010313
10030010526
10020010630
10020010641
10020010644

Harmonizing Flowsheets Data Concepts

BUCKET 1	BUCKET 2-SubBucket	PHS_Group Display Name	PHS_Row Display Names	PHS_Template Full Name	NYP_FSNAME	NYP_ITEM_NAME	NYP_ITEM_DESCRIPTION
Cardiac	Cardiac	Cardiac	Ectopy	IP SIMPLE ASSESSMENT	1) Vital Signs Flowsheet	vs_hr_ectopy	vs_hr_ectopy
Cardiac	Cardiac	Cardiac	Ectopy Frequency	IP SIMPLE ASSESSMENT	1) Vital Signs Flowsheet	vs_hr_ectopy_freq	Ectopy freq
Cardiac	Cardiac	Cardiac	Pulse	IP SIMPLE ASSESSMENT	1) Vital Signs Flowsheet	vs_vasc_pulse	Pulses
Cardiac	Cardiac	Cardiac	Clinical Monitor Alarms	IP SIMPLE ASSESSMENT	3) Respiratory Flowsheet	resp_check_alaramon	Alarms On
Cardiac	Cardiac	Cardiac	PR Interval	IP SIMPLE ASSESSMENT	5) Treatment Flowsheet	fs_tx_bedside_procs_12lead	12 Lead EKG
Cardiac	Cardiac	Cardiac	QRS Interval	IP SIMPLE ASSESSMENT	5) Treatment Flowsheet	fs_tx_bedside_procs_12lead	12 Lead EKG
Cardiac	Cardiac	Cardiac	QT Interval	IP SIMPLE ASSESSMENT	5) Treatment Flowsheet	fs_tx_bedside_procs_12lead	12 Lead EKG
Cardiac	Cardiac	Cardiac	QTc Interval	IP SIMPLE ASSESSMENT	5) Treatment Flowsheet	fs_tx_bedside_procs_12lead	12 Lead EKG
Cardiac	Cardiac	Cardiac	Cardiac Additional Assessments	IP SIMPLE ASSESSMENT	5) Treatment Flowsheet	fs_tx_cardiac_monitor	Cardiac Monitoring
Cardiac	Cardiac	Cardiac	Heart Sounds	IP SIMPLE ASSESSMENT	6) ICU Assessments	as_icu_cv_heart_sounds	Heart Sounds
Cardiac	Cardiac	Cardiac	Cardiac Rhythm	IP SIMPLE ASSESSMENT	6) ICU Assessments	as_icu_cv_rhythm	Rhythm
Cardiac	Cardiac	Cardiac	Cardiac Signs/Symptoms	IP SIMPLE ASSESSMENT	6) M/S Assessment	as_icu_cv_chest_pain	Chest Pain
Cardiac	Cardiac	Cardiac	Anginal Symptoms	IP SIMPLE ASSESSMENT	6) M/S Assessment	as_icu_cv_chest_pain	Chest Pain

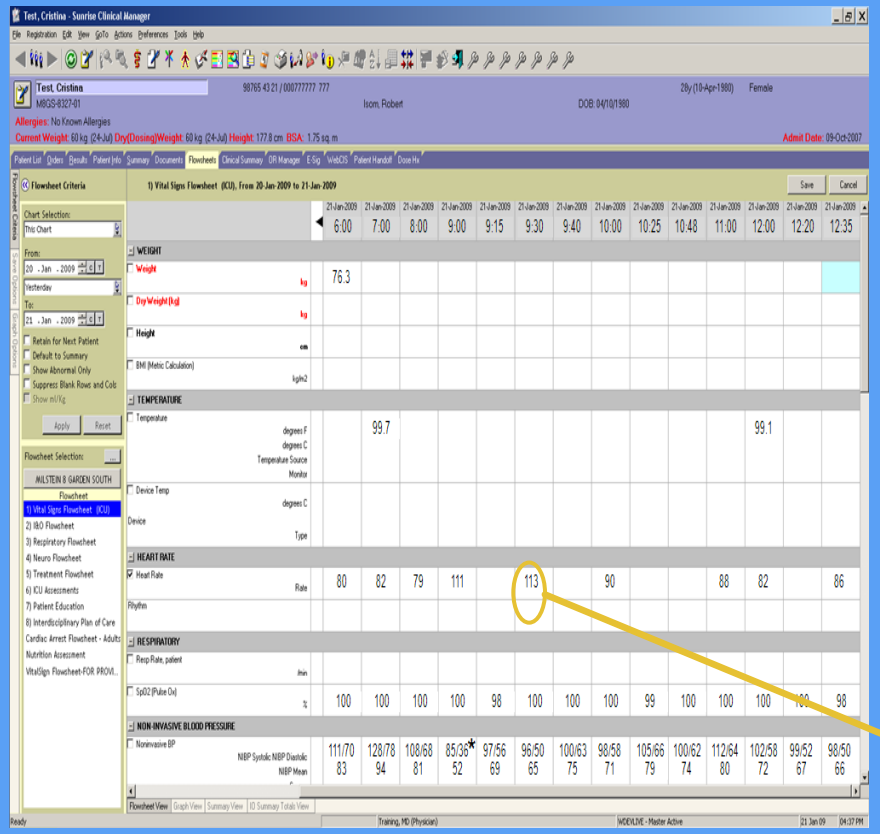
Nursing "Big Data" and CONCERN

- Nurses represent the largest group of health care providers
  - Contribute significant amounts of data to repositories.
- Nurses routinely collect, analyze and apply data and observations directly to patient care decisions.
- CONCERN patient cohort includes 160,000 BWH/PHS patients
  - >170 million flowsheet observations recorded by nurses!

Nursing "big data" can be used to identify and to protect patients at risk for deterioration.

Nursing Data IS Big Data: EHR Flowsheet Data

- Volume
- Velocity
- Variety
- Veracity
- Value



"Patient alternating nsr 80's and afib 120's. MD *X* aware. Patient given coumadin 2.5 as ordered. VSS. Lopressor given via duo tube."

"Levophed increased to 13 when MAP decreased after starting CVVH. MD notified."

CONCERN Data

Patient Demographics

Patient Acuity

Patient Encounter
(admission, transfer, discharge)

Flowsheet
Data points
Free-text comments

Notes
Nurse-written notes

Orders
Procedure Orders
Medication Orders

Medication Administration Record (MAR)

Labs
Results

Diagnoses
Admit diagnosis
Discharge diagnosis

Provider
Job title
Role

Department
Unit type (ICU vs. acute care)

Use I2b2 infrastructure and ontologies for harmonization

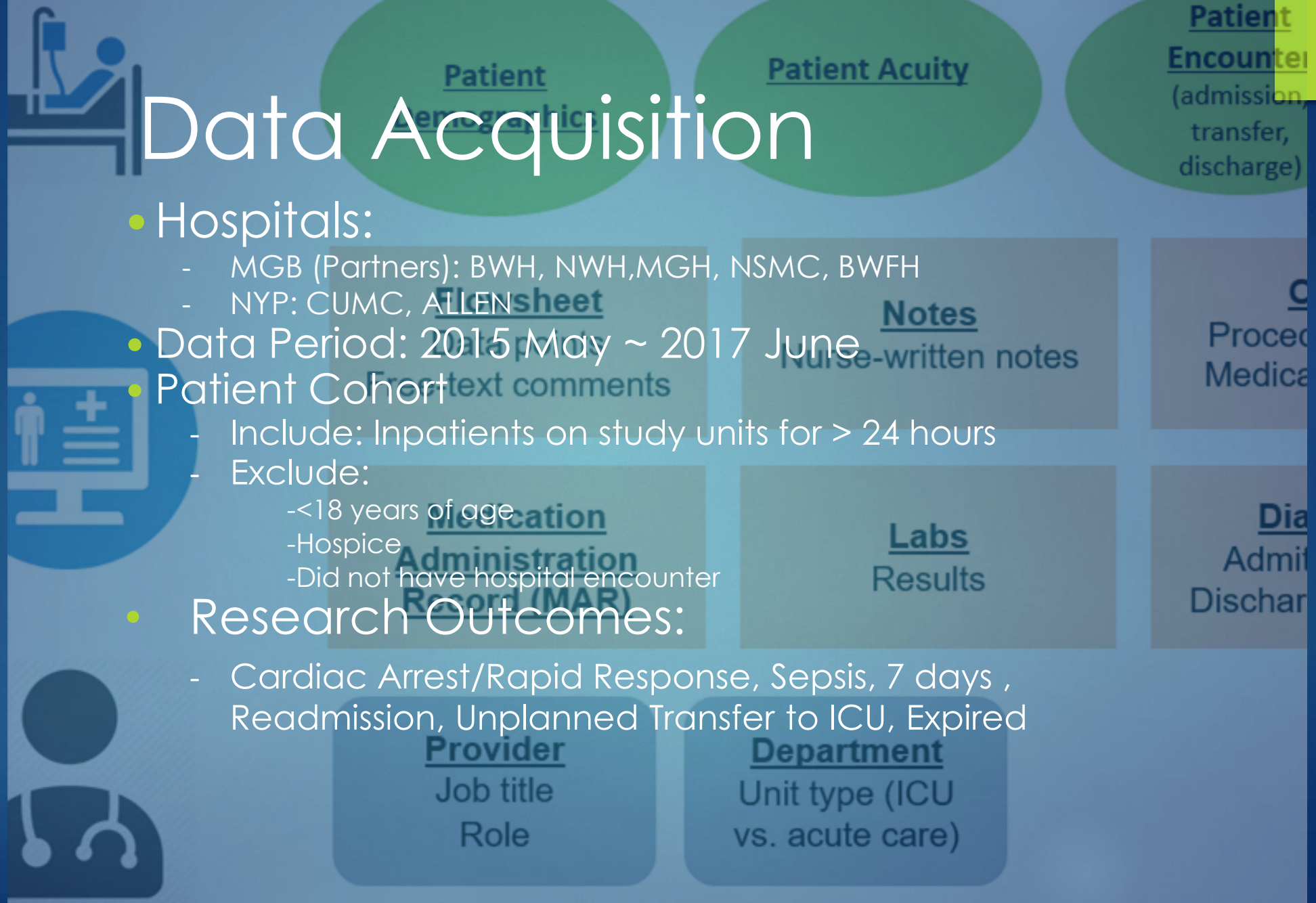
- Identify relevant concepts
- Leverage standardized terminologies to describe concepts
- Identify and map data across sites

Scalable & Shareable

Infrastructure and database architecture planning are essential for data to be useful
Critical when harmonizing data across two sites and two EHRs

Data Acquisition

- Hospitals:
  - MGB (Partners): BWH, NWH,MGH, NSMC, BWFH
  - NYP: CUMC, ALLEN
- Data Period: 2015 May ~ 2017 June
- Patient Cohort
  - Include: Inpatients on study units for > 24 hours
  - Exclude:
    - -<18 years of age
    - -Hospice
    - -Did not have hospital encounter
- Research Outcomes:
  - Cardiac Arrest/Rapid Response, Sepsis, 7 days , Readmission, Unplanned Transfer to ICU, Expired



Data Acquisition – Study Data set

	MGB (Partners)	NYP
Unique Patients	45,309	44,589
Encounter Cohort	61,782	64,842
Flowsheet Data	141,097,242 Rows	76,785,642 rows (Vitals Template) 170,541,580 rows (Assess. Template)
Notes	4,652,682 Rows	4,181,900 rows
Orders	Medication: 9,052,279 Rows Procedures: 5,872,679 Rows	Medication: 3,607,277 Diagnostic: 7,294,739 Other: 4,045,800
MAR(Medication Administration Records)	27,745,906 Rows	16,027,243 Rows

Data Validation

- Validation Principles
  1. Correct data extraction
  2. Appropriate Clinical explanation

Study Data Set (e.g., Flowsheet, Orders, Notes)	Study Outcomes
• Validate Data Types • Chart Review (Random sampling) • Statistical calculation (Min/Max/Median, Average of Frequency, Count per Month) • Compared with Hospital Policy • Compared Values between Sites	• Compared incident rates between sites • Compared with the literature • Chart Review (Random sampling)

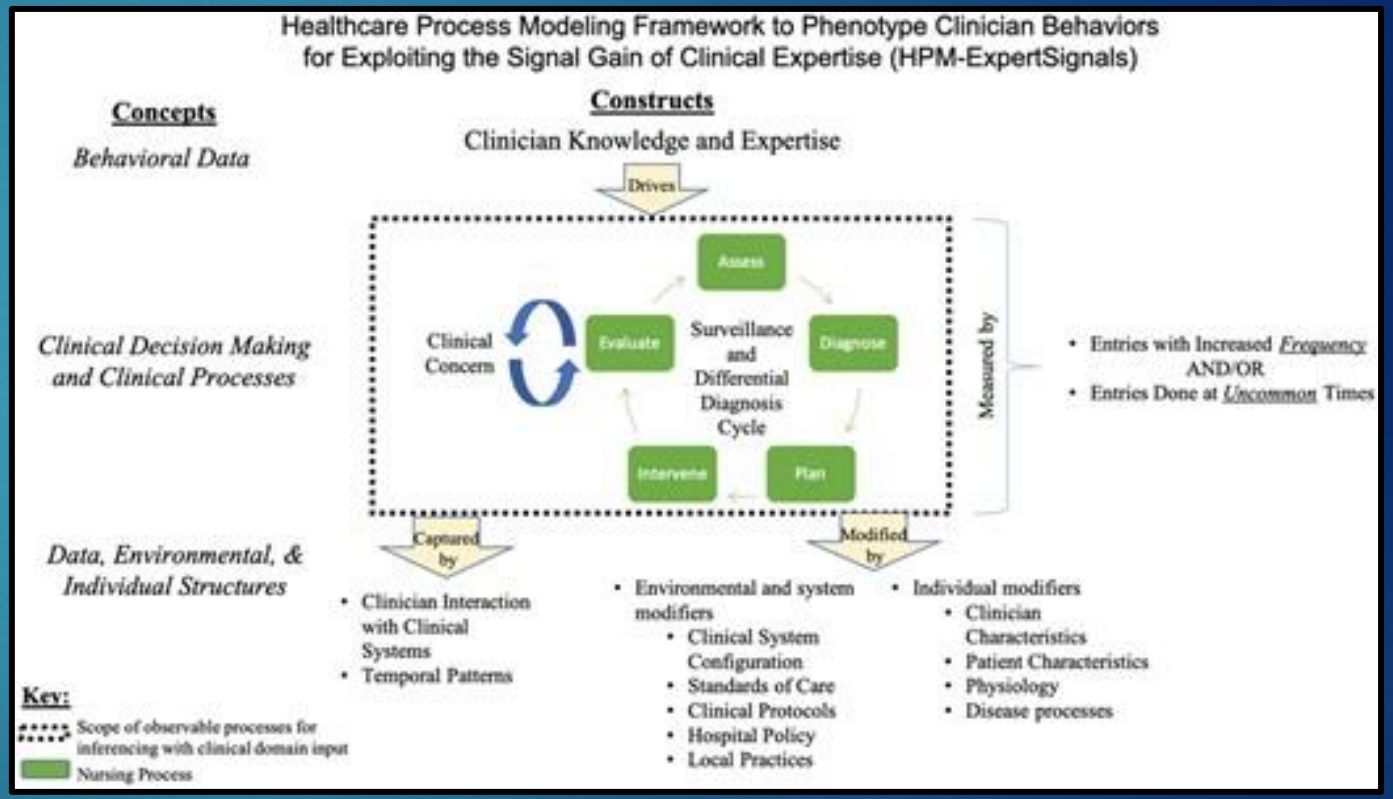
Data Cleaning: Ongoing search for EHR data errors

	Data Counts	Date Ranges
Admission Discharge Transfer (ADT)	468,003	2015-06-01 ~ 2018-05-07
Flowsheet (With LDA)	22,203,937	2015-05-08 ~ 2018-02-08
Flowsheet (WithOut LDA)	152,617,858	2015-05-18-~ 2018-02-13
MAR	40,944,742	2015-05-29 **~ 2047-06-05**
Notes	1,992,583	2015-05-28 ~ 2018-03-20
Order (Medication)	9,052,279	**1840-12-31 ~ 2106-09-17**
Order (Procedure)	9,677,510	2013-01-12 **~ 2024-07-10**

Pattern Discovery

Healthcare Process Modeling

- Signals of patient status and nursing workload buried in EHR that could be surfaced to drive situational awareness
  - Temporal patterns
  - Comments associated with structured data
  - Mentions of "concern" in unstructured text
  - Potential for CDS
- Sub-study Use Cases:
  - Documentation Burden
  - Medication Administration



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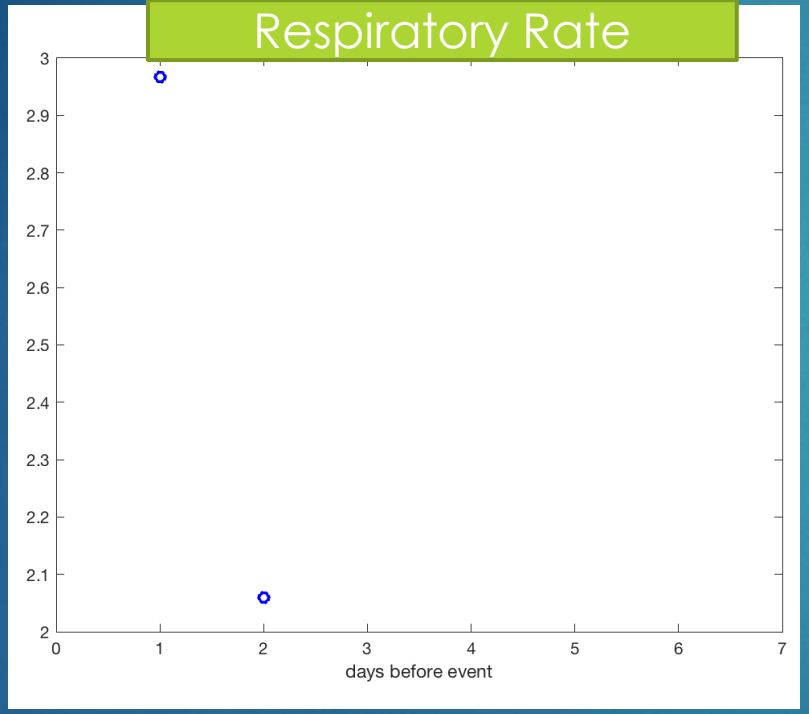
Healthcare process models of clinical concern (HPM-CC)

Greater Respiratory Rate Documentation
=> INCREASED RISK of death

Respiratory Rate

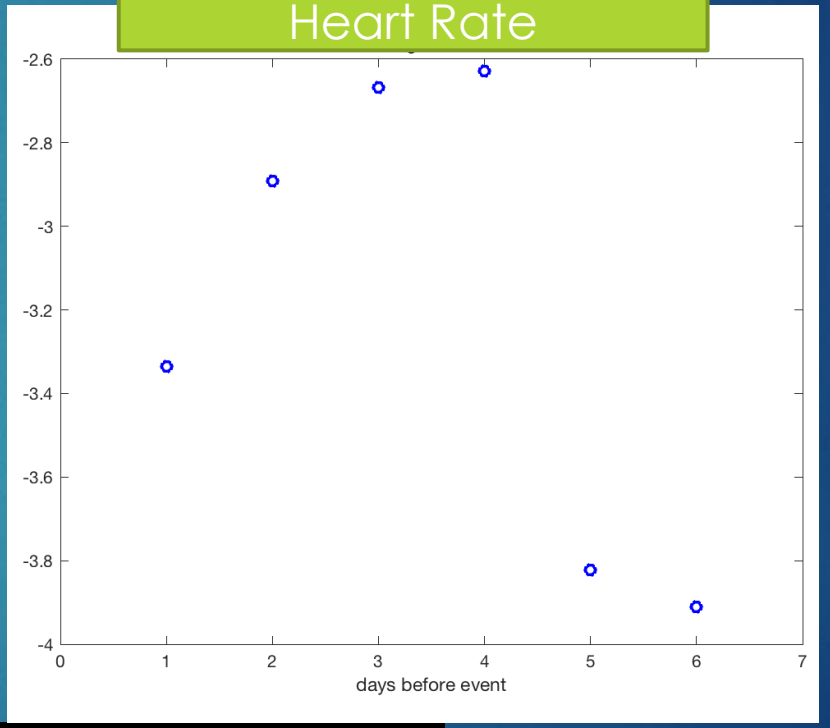
Odds ratio



Greater Heart Rate Documentation
=> DECREASED RISK of death

Heart Rate

Odds ratio



Longitudinal Logistic Regression Event: discharged alive or expired
Odds ratio
beta=0 implies no relationship between variate (dependent) and covariate (independent) variables
beta > 0 implies the risk is INCREASED when covars are increased
beta < 0 implies the risk is DECREASED when covars are increased

Pattern Discovery Use Case #1:

Quantifying and Visualizing Nursing Flowsheet Documentation

1. Purpose: To investigate flowsheet documentation burden by quantifying the number and frequency of data points entered into an EHR using analyses of data entry log-files.
2. Site/setting: Acute care general medicine (4 units) and ICU (2 units) at AMC in Boston January – December 2017.
3. Methods: Captured mean number of data entries per nurse (# flowsheet data points documented during 12-hour shifts/# nurse users that documented during that same time period)
    1. a) Mean number and standard deviation of data points documented
    2. b) Mean number and standard deviation of users that documented
    3. c) Mean number of data points per user

Collins S, Couture B, Kang MJ, Dykes PC, Schnock K, Knaplund C, Chang F, Cato K. Quantifying and Visualizing Nursing Flowsheet Documentation Burden in Acute and Critical Care. AMIA Annu Symp Proc. 2018 Dec 5;2018:348-357.

QUANTIFYING Nurse Documentation Burden

Mean Flowsheet data points per 12 hour DAYTIME shift								
Unit Type		Total data points for unit (SD)	RNs on unit (SD)	Data points /RN	Device data points /RN	Manually entered data points/ RN N (%)	Manually entered data points per RN/hour	1 data point manually documented every:
ICU	Unit A	5531.45 (1210.82)	6.82 (1.20)	810.50	160.31	650.19 (80%)	54.18	1.11 minutes
	Unit B	5522.36 (1168.48)	7.01 (1.16)	787.37	153.93	633.44 (80%)	52.79	1.14 minutes
Acute Care	Unit C	1993.36 (747.02)	2.83 (1.07)	705.37	43.29	662.09 (94%)	55.17	1.09 minutes
	Unit D	2071.64 (838.38)	2.94 (1.17)	704.99	49.13	655.86 (93%)	54.65	1.10 minutes
	*nurse to patient ratio in ICU is 1:1 to 1:2, depending on patient acuity; ±nurse to patient ratio in acute care is 1:3 for day shift							

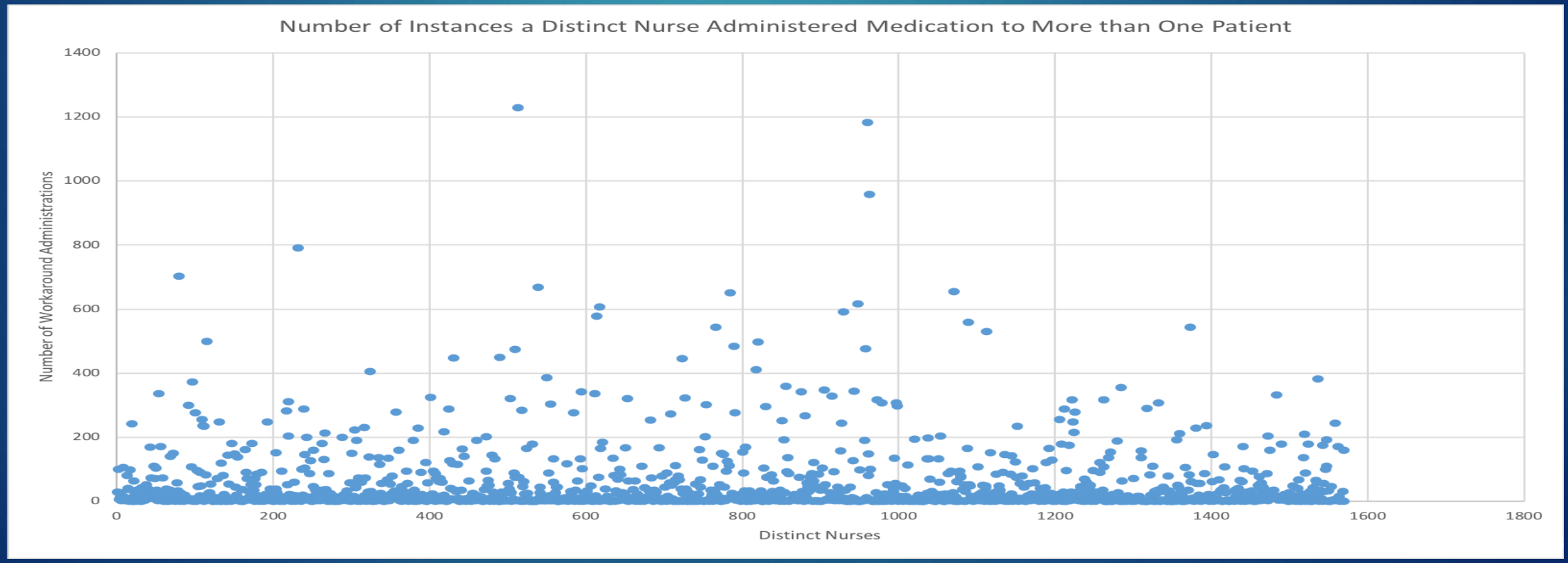
Pattern Discovery Use Case #2:

Signals of Nurse Workarounds in Electronic Medication Administration Record (EMAR) Data

- Analyzed CONCERN eMAR log files
  - Queried two years of eMAR data
  - Two hospital in Northern Manhattan,
    - 745-bed adult facility in an academic medical
    - 300-bed community hospital
  - 2,280,241 medication administrations
  - Extracted timestamp from eMAR logfiles
  - Charted medications for more than one patient within 60 seconds

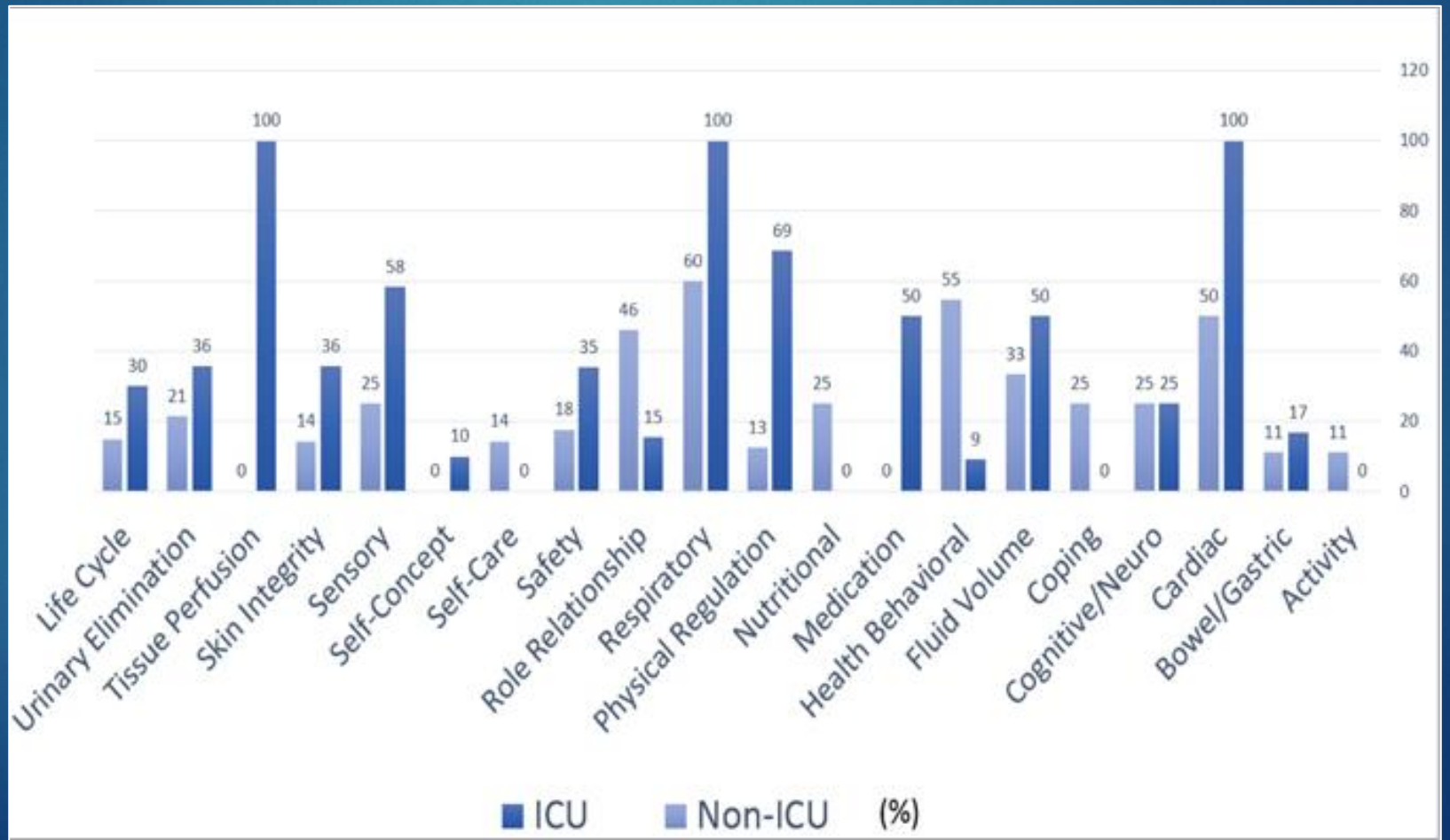
Findings: Signals of Nurse Workarounds in Electronic Medication Administration Record Data

- Workarounds are a signal for important workflow phenomena
  - 25% of nurses performed this "workaround" at least once in two years
  - 10% of nurses accounted for 76% of "workarounds"
- Analyses need to take these workaround biases into consideration
  - Removal of outliers
  - Analyze on a shift level



Approaches for NLP of Nursing Concern in Notes across 2 Healthcare Systems

CCC Concepts rated by SMEs for Nursing Concern in ICU and non-ICU Settings

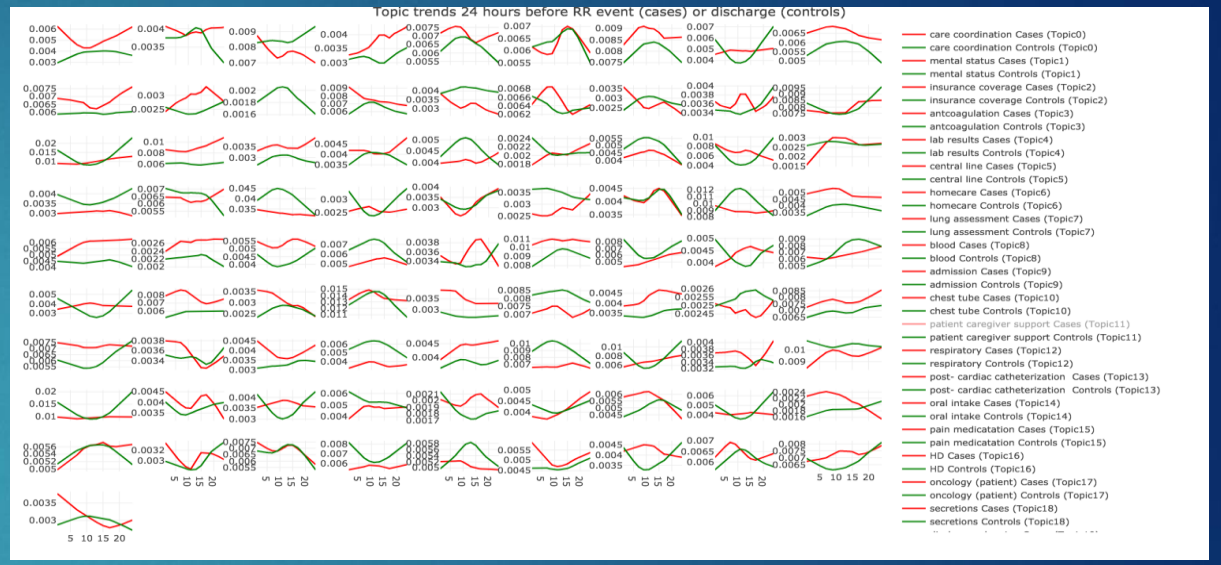


Flowsheet Topic Modeling of Subjective Nursing Topics

LDA Topic Modeling Results – Survival analysis for Rapid Response Events

Title	Coef.	P value
Admission	0.07576	0.0011
edema assessment	0.06667	0.0423
overnight status	0.04692	0.3991
oral intake	0.03526	0.2623
alertness status	0.02722	0.1607
homecare	0.01581	0.6073
skin assessment	0.01281	0.545
clinical concern	0.0123	0.759
urinary catheter	0.00519	0.9313
antibiotic dosing	-0.00407	0.9148
skin protection	-0.01537	0.7248
mental status	-0.01785	0.4403
medication frequency	-0.0378	0.0883
ng tube status	-0.04203	0.3742
heart failure medications	-0.05812	0.0206
discharge planning	-0.06033	0.0078
nurses concerns	-0.11882	0.0169

Topic trends of rapid-response cases (red) versus controls (green)



- Out of the 71 titles, 17 were found significant in one-sided testing.
- Extended Cox model found significant association for 5 of them between the topic presence and RR event.
  - coefficient >0: increases hazard
  - coefficient <0 decreases hazard

Identifying CONCERN Concepts in Free Text Data

Purpose:

TO IDENTIFY AND DEFINE NURSE CONCERN CONCEPTS AND TERMS ABOUT PATIENT DETERIORATION, WHICH CAN BE USED TO SUPPORT AUTOMATED TASKS, SUCH AS NATURAL LANGUAGE PROCESSING, RISK PREDICATION, AND CLINICAL DECISION SUPPORT

Kang MJ, Dykes PC, Korach TZ, Zhou L, Schnock KO, Thate J, Whalen K, Jia H, Schwartz J, Garcia JP, Knaplund C, Cato KD, Rossetti SC. Identifying nurses' concern concepts about patient deterioration using a standard nursing terminology. Int J Med Inform. 2020 Jan;133:104016.

CONCERN Sentiment Analysis: Domain expertise needed for each step

Database design and setup

- Extraction, cleaning, harmonization, structuring

Feature selection

- Identification based on workflows, clinical "hunches"

Feature interpretation

- Signal meaning/explanation from clinical perspective

Model translation

- Clinical significance, not only predictive power

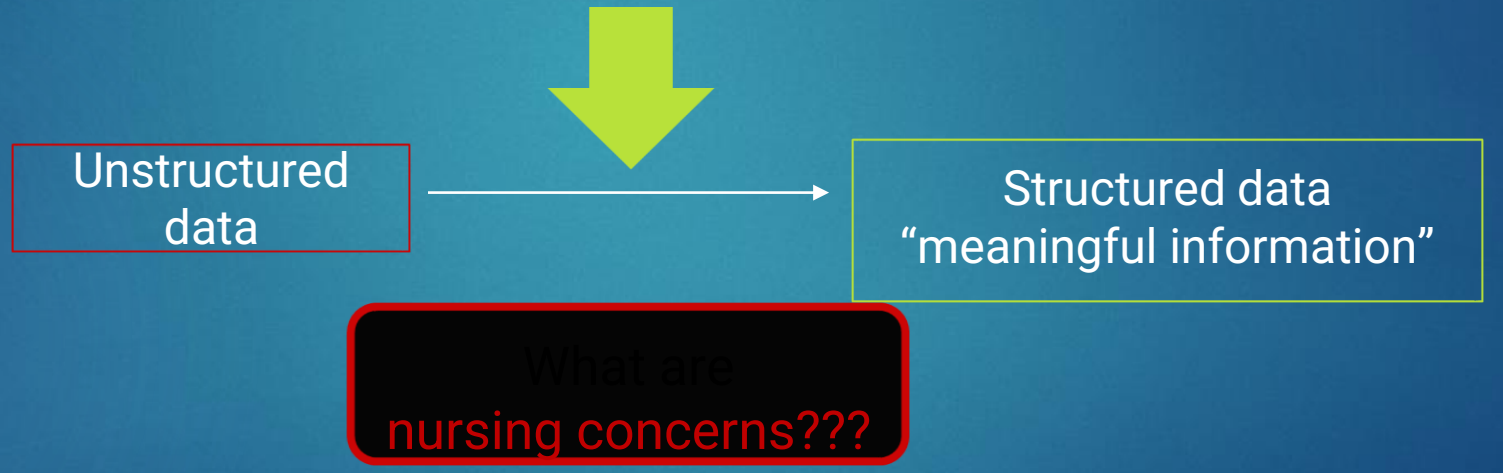
CDS design

- Useful and easy to use

Extracting Nursing Concerns

Automated text analysis

Natural language processing,
machine learning, data mining

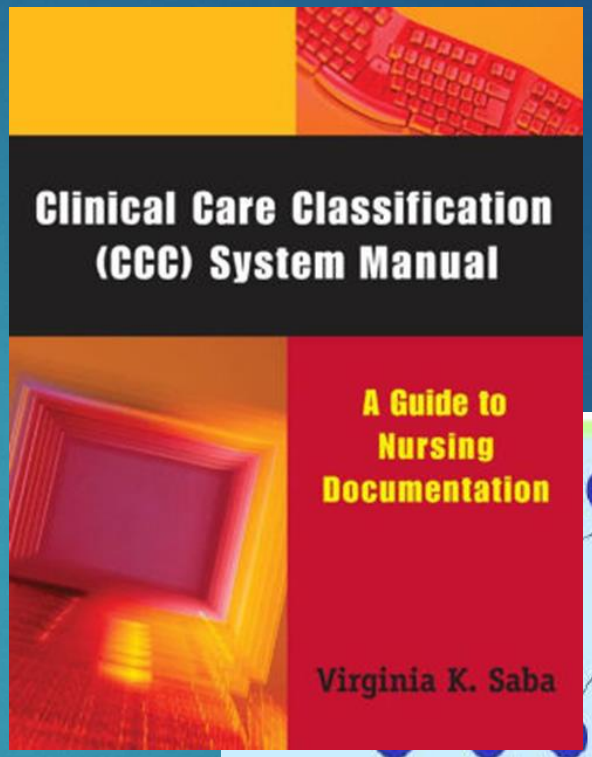


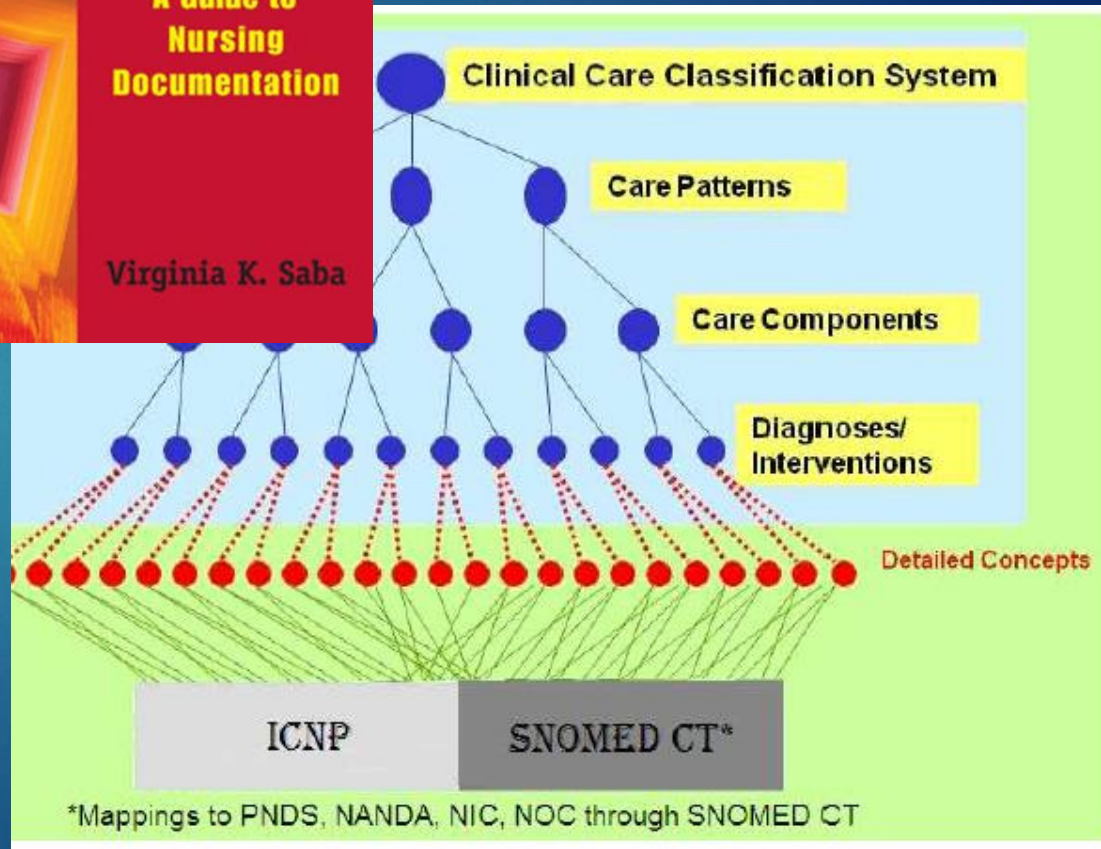
'Concern' is based on an individual nurse's intuition and subjective judgement

→ Difficult to clearly define the phenomenon in a standardized format

Clinical Care Classification System (CCC)

- Standardized nursing terminology
- 21 Care Components, 176 nursing diagnoses and 201 nursing intervention concepts
- Offers nursing conceptual framework → capture subjective descriptors under the higher level CCC concepts
- CCC is linked with other reference terminologies → making it easy to further map concepts to granular terms

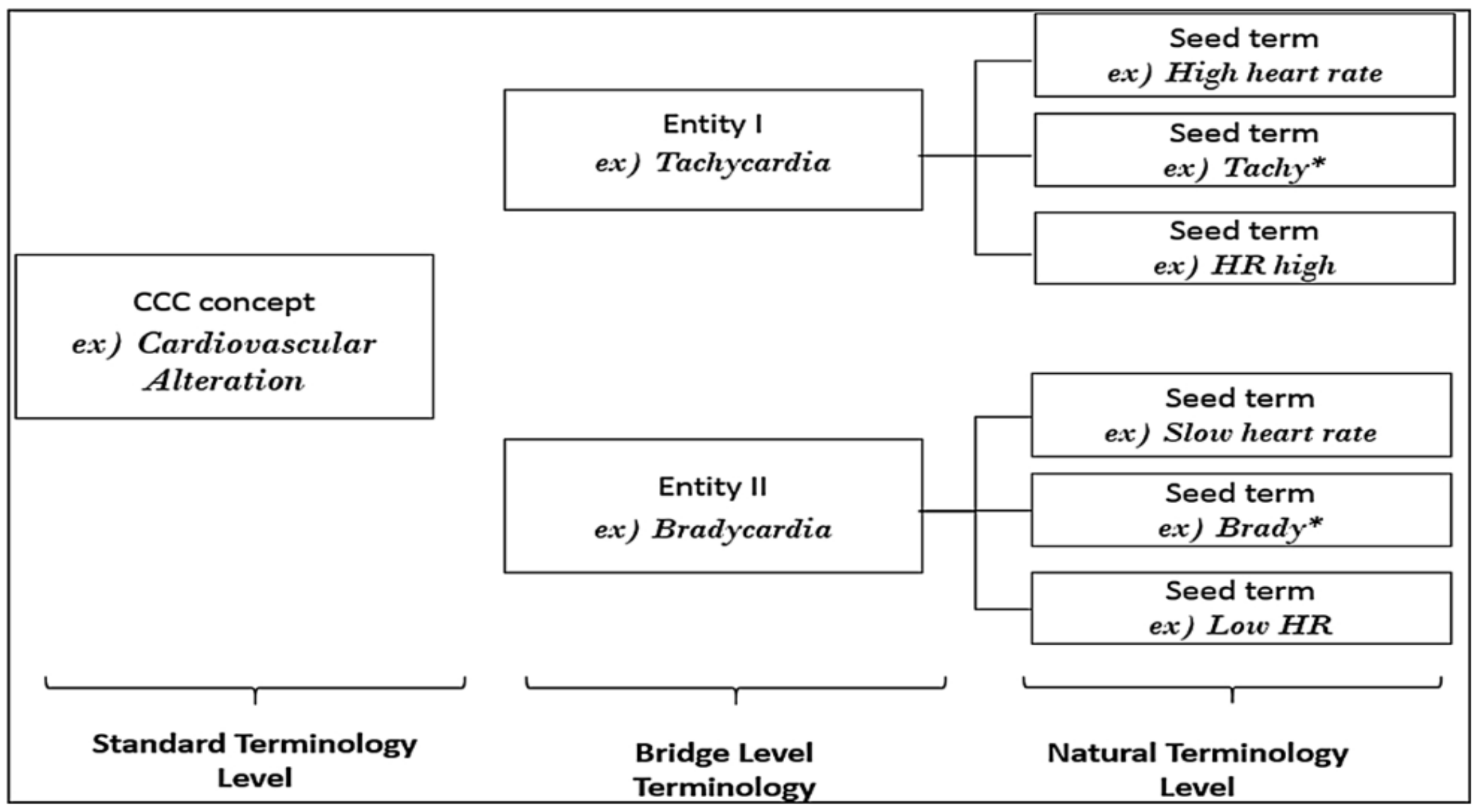




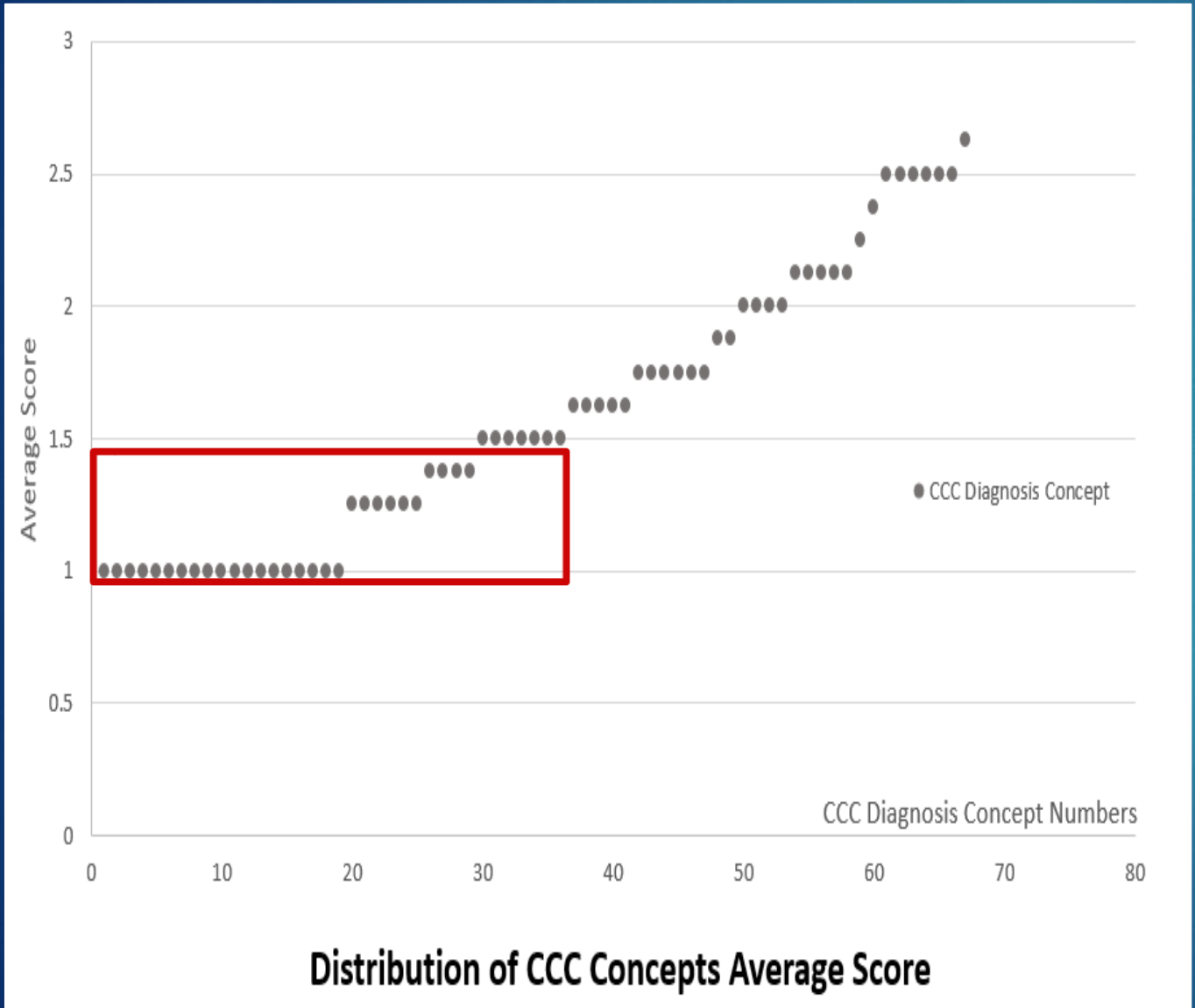
Methods

- Group consensus meetings
- Five nurse subject-matter experts (SMEs)
- Question: what concepts do nurses document in nursing notes when they feel a patient is at risk of deteriorating?
- How: reviewed and graded the individual CCC concepts
  - 3 scales: 1: High concern, 2: moderate concern, 3: No concern
- Scored grades within six types of clinical units
  - Acute care units: medicine, surgery
  - Intensive care units: MICU, SICU/Trauma ICU, Cardiac ICU, Neuro ICU

- Methods


CCC concept
ex) Cardiovascular Alteration
Entity I
ex) Tachycardia
Entity II
ex) Bradycardia
Seed term
ex) High heart rate
Seed term
ex) Tachy*
Seed term
ex) HR high
Seed term
ex) Slow heart rate
Seed term
ex) Brady*
Seed term
ex) Low HR
Standard Terminology Level
Bridge Level Terminology
Natural Terminology Level

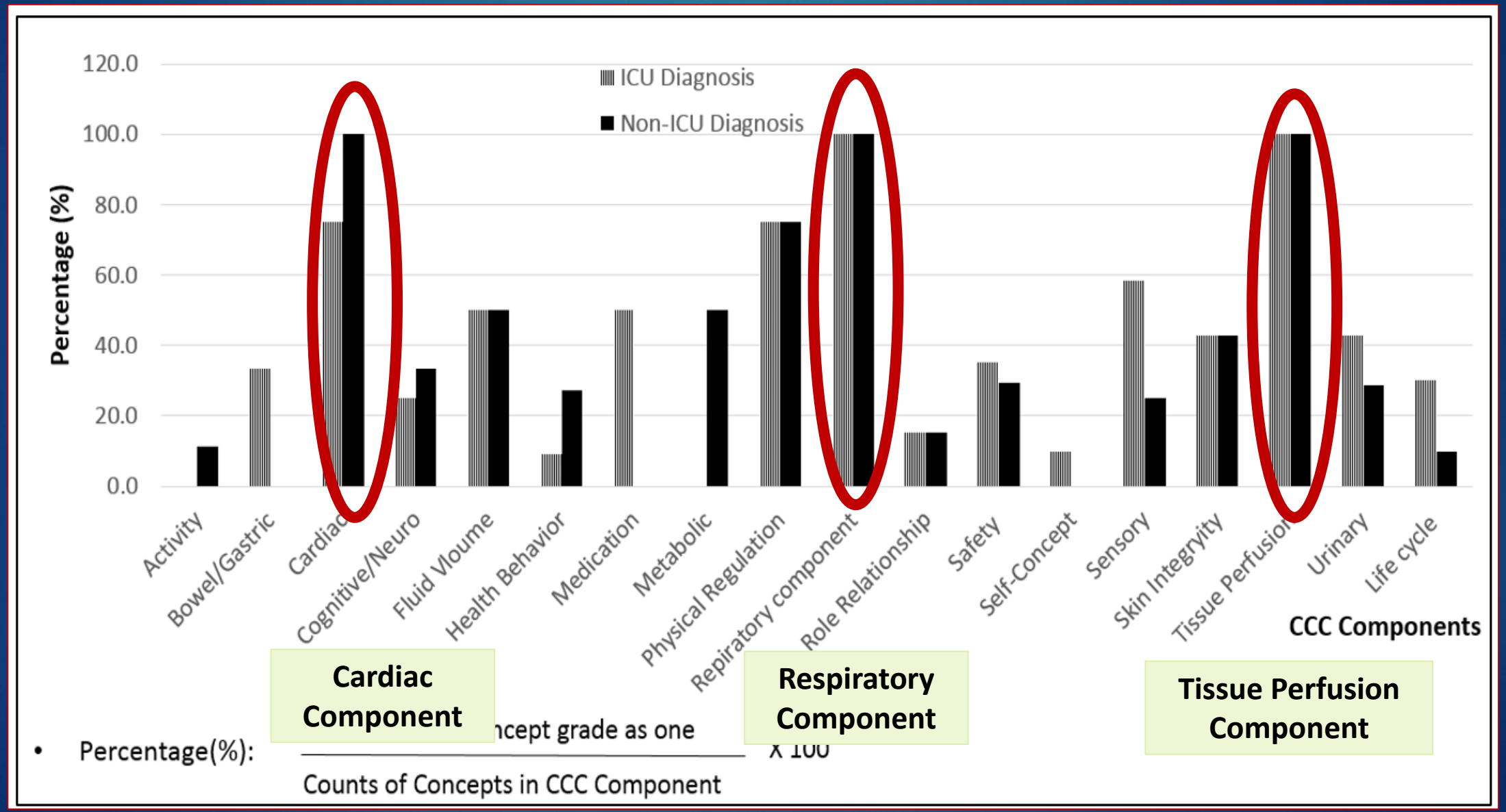
Results



- Scored as grade one by SMEs: 67/176 CCC diagnosis concepts
- Based on clinical judgement threshold for inclusion score: 1.357
- Exclusion threshold were individually reviewed by SMEs to confirm exclusion

29 Concepts

Results: Percentage diagnoses concepts rated as "1" per CCC Care Component



Core Concepts Count per CCC Component

Average Grade	CCC Component	CCC Concepts
1.0	Cardiac	Blood Pressure Alteration; Cardiac Output Alteration; Cardiovascular Alteration
	Cognitive/Neuro	Confusion; Cerebral Alteration
	Respiratory	Breathing Pattern Impairment; Gas Exchange Impairment; Respiration Alteration
	Role Relationship	Communication Impairment; Verbal Impairment
	Sensory	Acute Pain; Visual Alteration
	Safety	Suicide Risk; Violence Risk
	Fluid Volume	Fluid Volume Deficit
	Tissue Perfusion	Tissue Perfusion Alteration
	Physical Regulation	Hyperthermia; Hypothermia; Intracranial Adaptive Capacity Impairment
1.25	Coping	Airway Clearance Impairment
	Physical Regulation	Autonomic Dysreflexia
	Safety	Injury Risk; Self-mutilation Risk
	Fluid Volume	Fluid Volume Excess
	Urinary Elimination	Urinary Elimination Alteration
1.35	Fluid Volume	Fluid Volume Alteration
	Physical Regulation	Infection
	Skin Integrity	Peripheral Alteration
	Cognitive/Neuro	Thought Processes Alteration

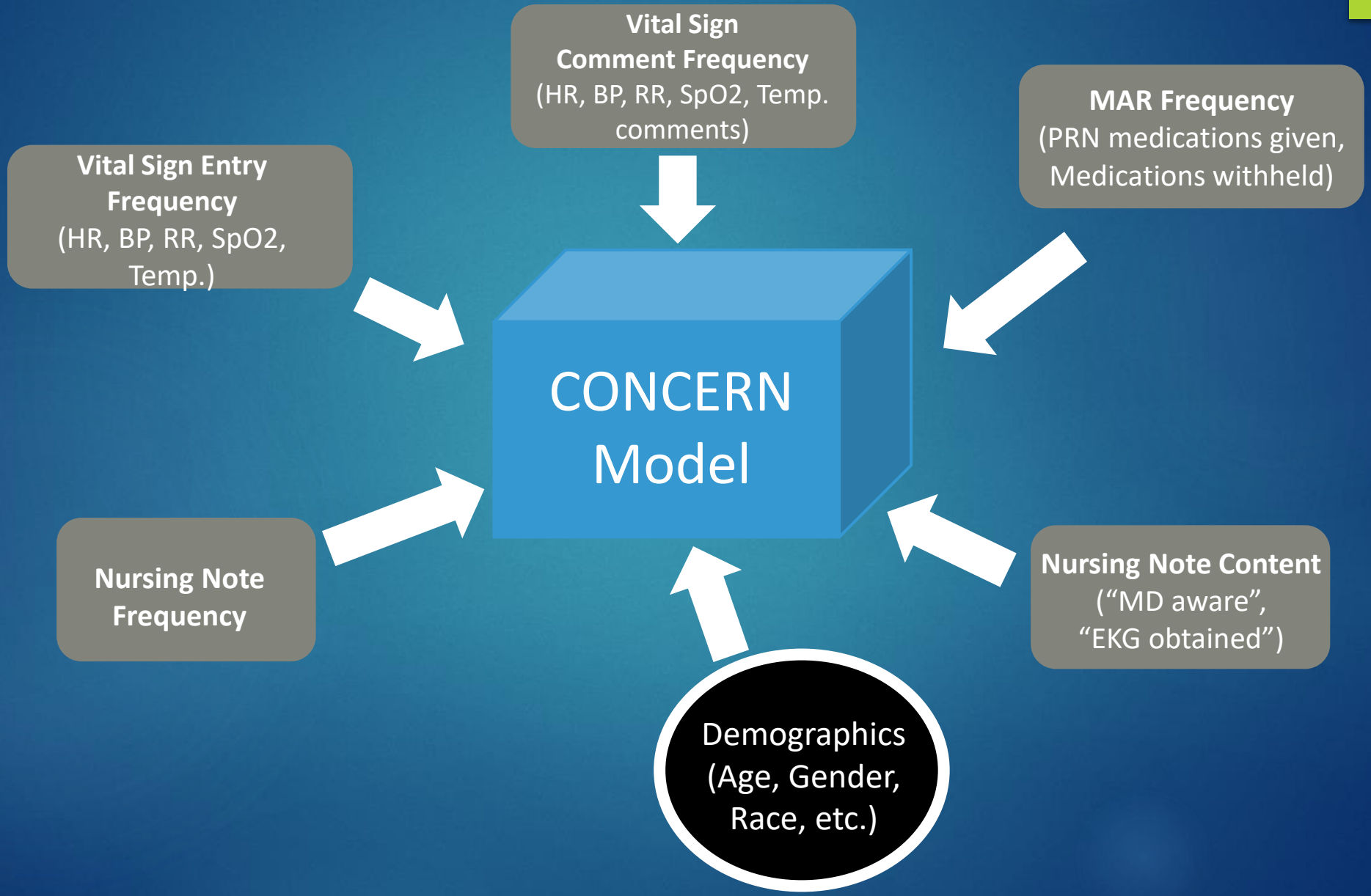
	ICU		Non- ICU	
CCC Component	Medicine (MICU)	Surgery (SICU, Trauma ICU)	Medicine	Surgery
Bowel/ Gastric	– Diarrhea	– Diarrhea – Fecal Impaction – Gastrointestinal Alteration	–	–
Physical Regulation	– Autonomic Dysreflexia – Hyperthermia – Hypothermia – Thermoregulation Impairment – Intracranial Adaptive Capacity Impairment	– Autonomic Dysreflexia – Hyperthermia – Hypothermia – Thermoregulation Impairment – Intracranial Adaptive Capacity Impairment – Infection	–	–
Skin Integrity	– Latex Allergy Response – Peripheral Alteration	– Latex Allergy Response – Peripheral Alteration – Skin Incision	– Skin Integrity Impairment – Latex Allergy Response	– Skin Integrity Impairment – Latex Allergy Response – Peripheral Alteration
Urinary Elimination	– Urinary Elimination Alteration – Renal Alteration	– Urinary Elimination Alteration – Renal Alteration – Urinary Retention	– Urinary Elimination Alteration	– Urinary Elimination Alteration – Urinary Retention

- Discussion/Conclusion
  - Final 29 CCC diagnosis concepts
    - Patients' physiological status
    - Common condition indicators for all inpatients across unit type and patient acuity
    - The CCC concepts with average grade may mask importance in particular setting

Activity Intolerance Scored 2	**Acute Care : 1** **ICU Setting : 2/3**

    - Future research: linking entities and seed term to other standard terminologies

CONCERN Predictive Model



The CONCERN Predictive Model

Validation

- Multinomial Gradient Boosted Machine (GBM) model selected
- Built on random 12-hour time slices to predict (over the next 24 hours) whether a patient is discharged, will still be in the hospital, or has a negative event
- Trained on 70% of the dataset – 30% was used for 10-fold cross validation

Model Performance

Setting	Accuracy	Precision	Recall	Logloss	AUC
ICU	0.970938	0.431373	0.594595	0.073695	0.934683
ACU	0.973341	0.813559	0.643935	0.089369	0.955982

Better lead time than other early warning scores (EWS)

How is CONCERN Different than Other EWS?

	Patient Deterioration (Early Warning System)	24 Hour Mortality	ICU Readmission	30-Day Readmission
MEWS	x	x		
CONCERN	x	x		
Rothman Index		x	x	x

"Clinically, deteriorating patients in general wards either die or are transferred to ICU. This criterion resulted in exclusion of the Rothman Index, which predicts "death within 24 hours" but not ICU transfer."

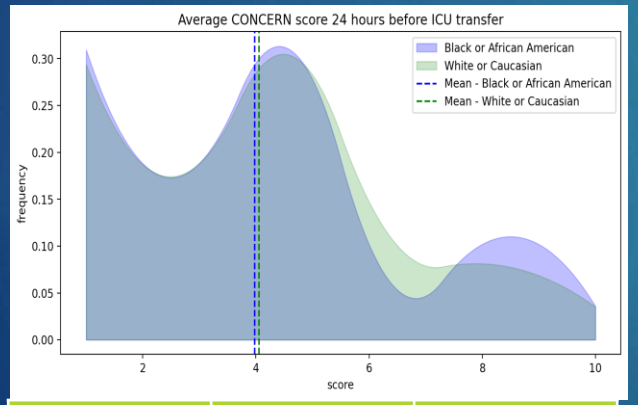
Linnen et. al. Statistical Modeling and Aggregate-Weighted Scoring Systems in Prediction of Mortality and ICU Transfer: A Systematic Review. ***J Hosp Med****. 2019 Mar; 14(3): 161–169.*

How is CONCERN Different than Other EWS?

Racial Bias: Comparison of 3 Early Warning Systems

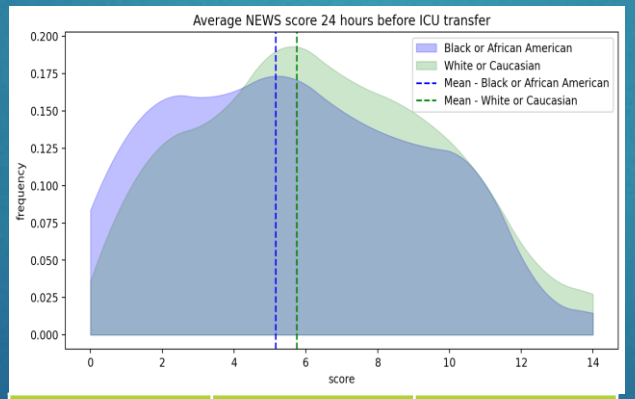
- Anticipated that race (and other patient demographics) would play a role in an EWS based on documentation patterns (CONCERN). Demographic information was included in the model building and postprocessing steps to reduce racial bias in the score.
- NEWS and MEWS based on a patient's physiological state and do not account for potential racial biases. White or Caucasian patients who are transferred to the ICU receive a statistically higher average scores then Black or African American patients.

CONCERN



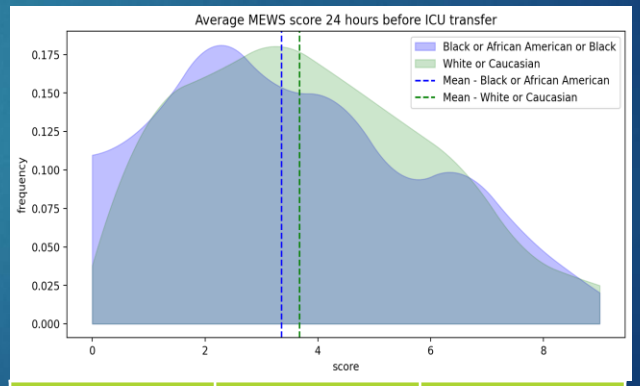
Mean – Black or African American	Mean – White or Caucasian	P-value
3.976190	4.053905	**0.210805**

National Early Warning Score (NEWS)



Mean – Black or African American	Mean – White or Caucasian	P-value
5.161055	5.752857	**0.009656**

Modified Early Warning Score (MEWS)



Mean – Black or African American	Mean – White or Caucasian	P-value
3.355838	3.673857	**0.046306**

Benefits of CONCERN approach to EWS

- Approaching EWS modeling from different paradigm
  - Data types (metadata patterns) & data temporality (simulated real-time prospective analysis)
- Simple rule
  - Interpretable/not black box
  - Based on frequencies of documentation
  - Derived from expert knowledge of practice patterns
- Triggered alarms 42 hours earlier
  - Highly clinically significant
  - Machine learning models have equivalent or slightly better performance than MEWS but no reported lead time (e.g., Churpek et al.)
- Confirmed that how, when, and why a clinical observation is documented impacts information signals

Concern Specific Aims:

Aim 1. Perform analytics of existing nursing data and documentation patterns to confirm predictive factors and notification thresholds for patients at risk of adverse outcomes in the hospital

- Natural Language Processing, Machine Learning, Predictive analytics

Aim 2. User-centered design and testing of CONCERN SMART App; Prototype development and simulation testing

Aim 3. Implementation and evaluation of the impact of the CONCERN SMART App on patient outcomes

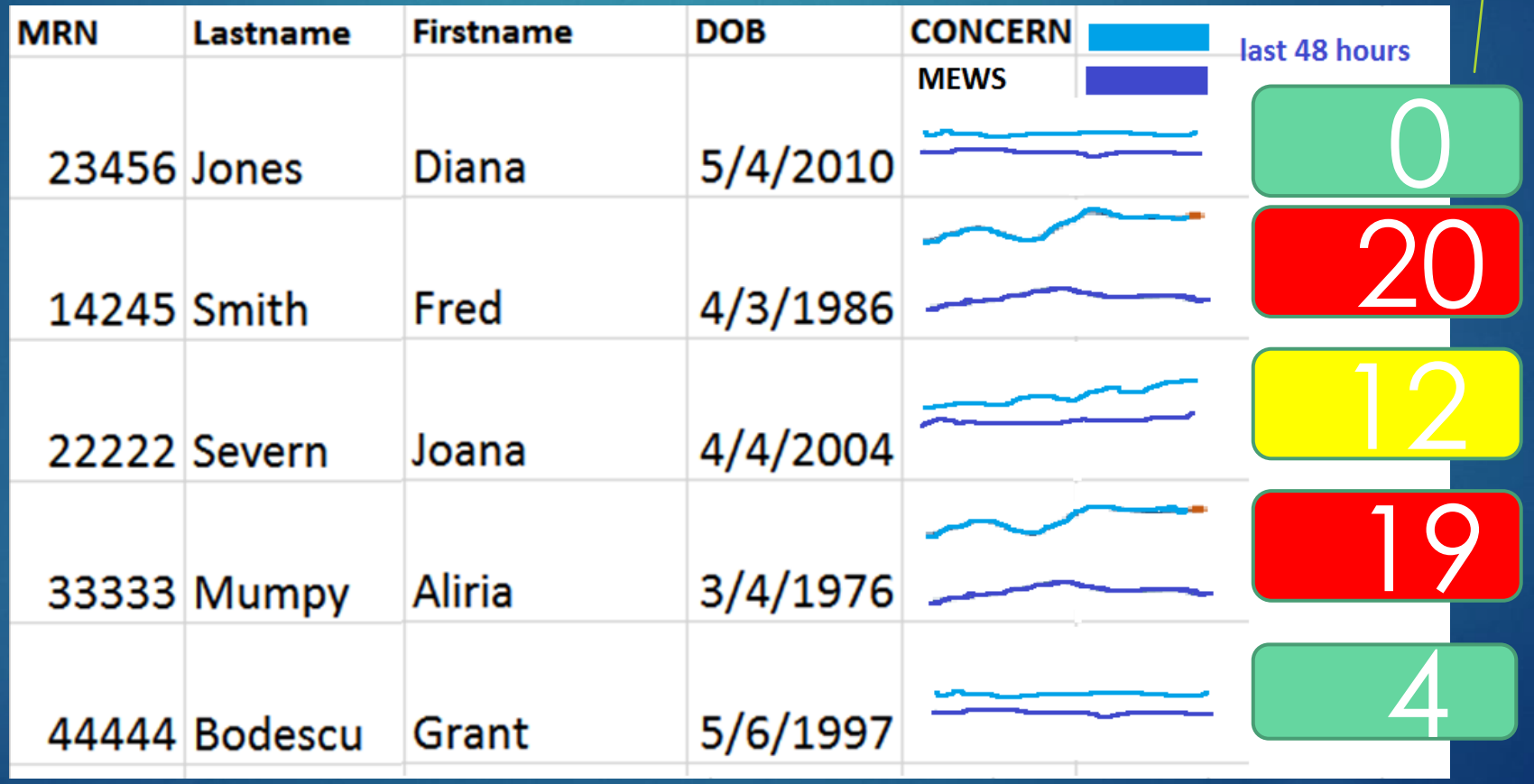
- **Primary outcomes:** in-hospital mortality and length of stay
- **Secondary outcomes:** cardiac arrest, unanticipated transfers to the intensive care unit, and 30-day hospital readmission rates.

CONCERN: User-centered Design

- Goals: To determine how data should be presented
  - Best screen layout
  - Pop-up warning, dashboard icon, message
  - Workflow integration
- Methods:
  - Focus groups/interviews to identify user interface requirements
  - Iterations of high-fidelity prototypes
    - ICU and non-ICU nurses and physicians

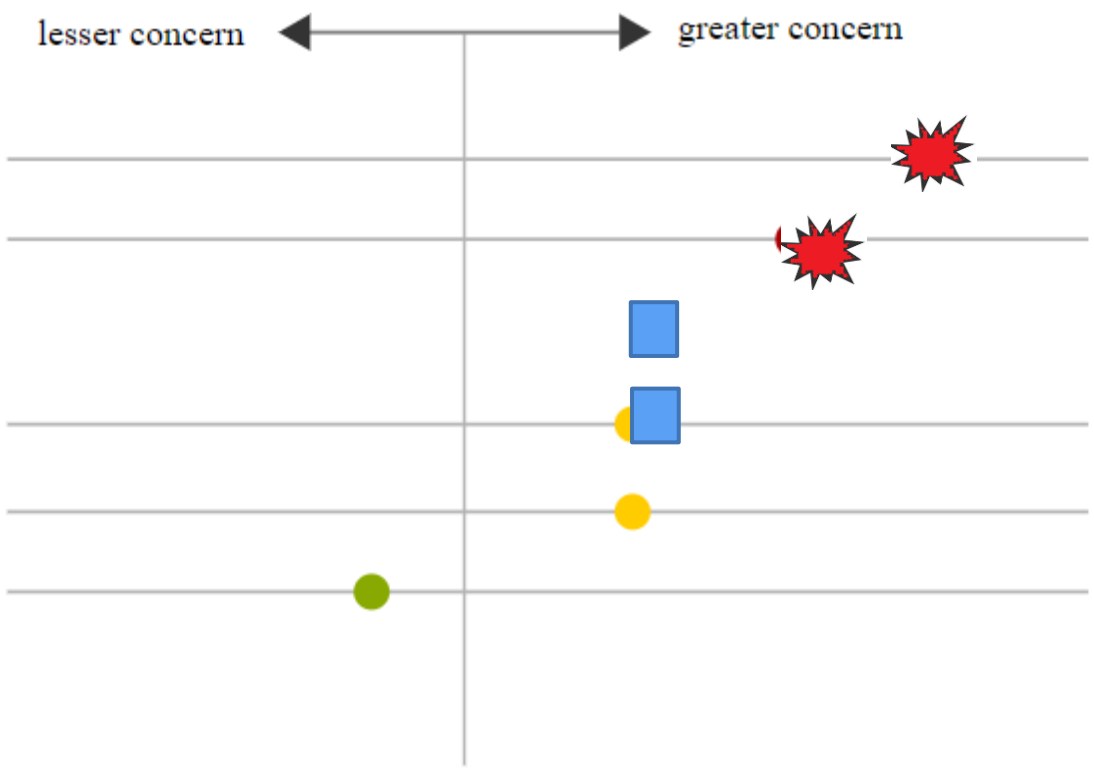
Screen #1 – patient list

clickable



Screen #2 – rapid at-a-glance explanation

Alert! The CONCERN algorithm (**PPV+=88%**) shows this patient fits the profile of those at risk:



In the last 48 hours:

> 22 sets vitals documented

> 5 comments

Note content indicators:

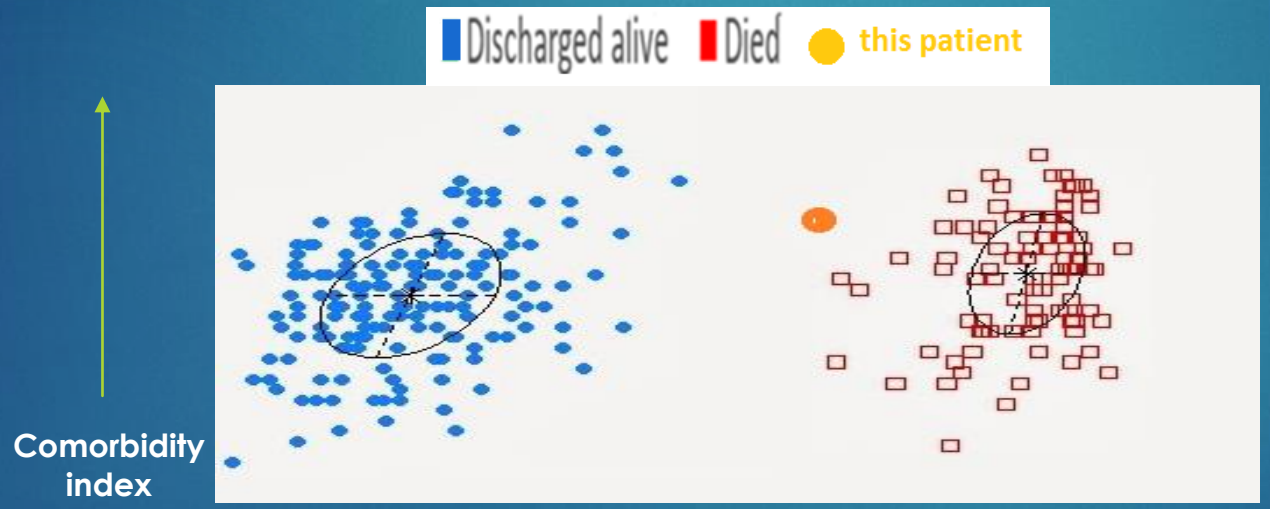
Highlights data (O2sat, BP, Glc, HR, RR)

No 'intervention', 'assessment' or 'MD aware'

Documentation sentiment analysis

Screen #3 Drill down to detailed evidence

- **Alert!** The CONCERN algorithm (**PPV+=88%**) shows this patient fits the profile of those at risk:



Note content indicators: Document content
Not MD aware

More info…

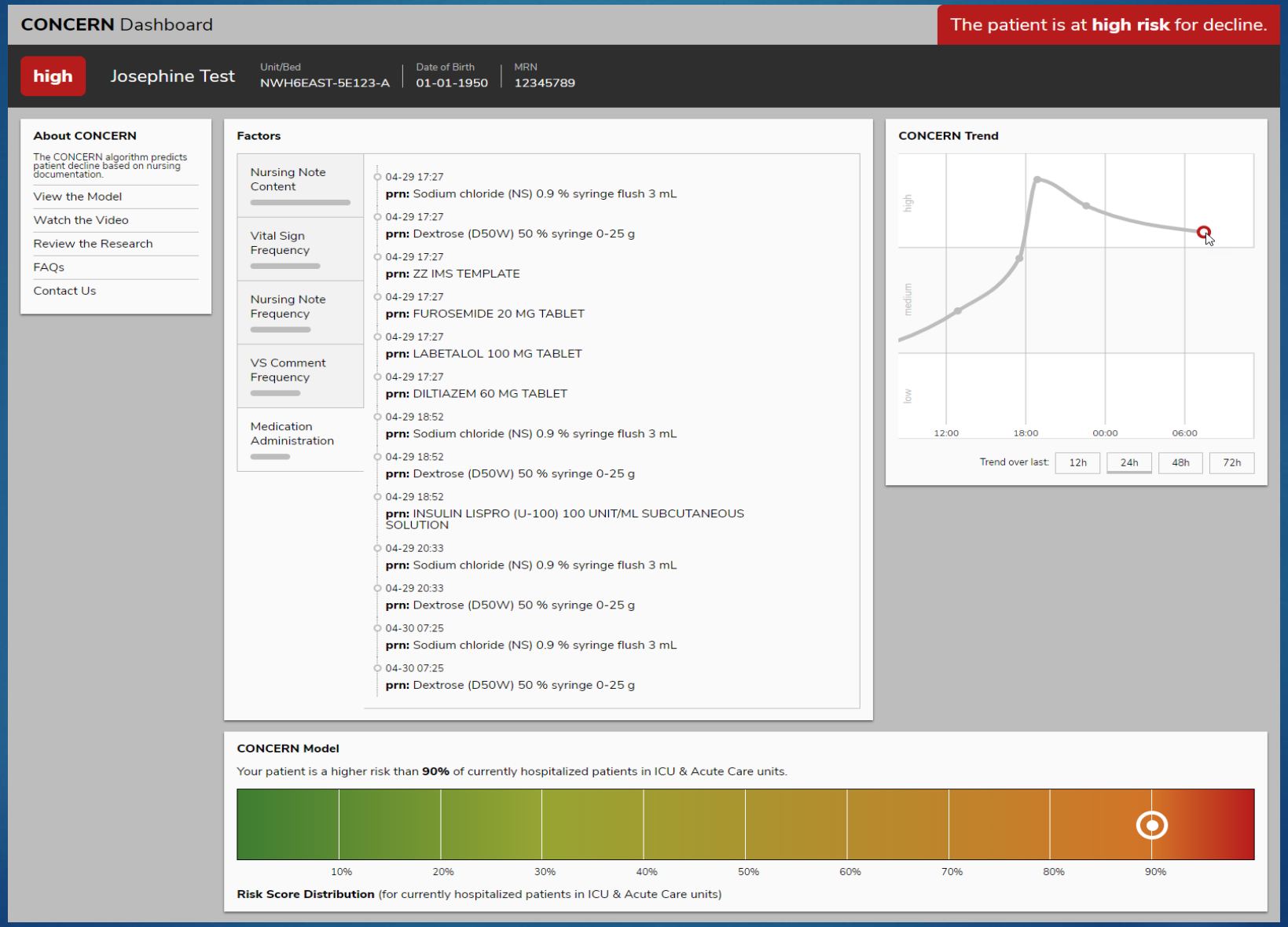
Collins S, Cato K, Albers DJ, Scott K, Stetson PD, Bakken S, et al. *Relationship Between Nursing Documentation and Mortality*. Am J Crit Care 2013; 22: 306-13.

CONCERN Intervention: Configured in Patient List

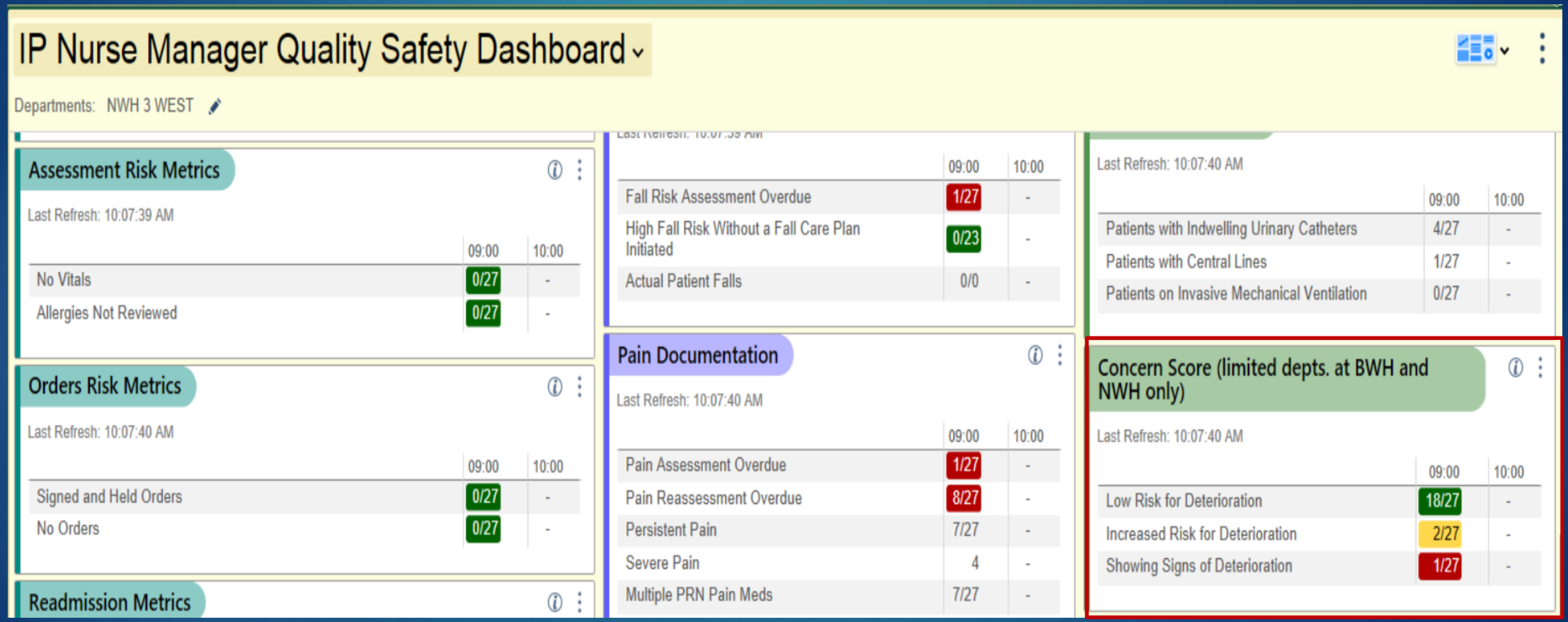
My patients 5 Patients — Refreshed just now — Search All My Lists

Patient Name / Age / Sex	Unit/Bed	New Messages	Unacknowledged Orders	Med Due	New Rslt Flag	Reassess Pain	CONCERN Score	Admit RN Req Doc	Shift Req Doc	Code Status	Problem	Respondin Clinician	Med Over Pend	Signed/Held
Concern, Martin (91yrs M)	BWH SH 9E 903-1	—				—	*			None on file	None	—		—
Concern, Pal (78yrs M)	BWH 11D 75-1	—		—	—	—	*			None on file	None	—		—
Concern, Sacu (82yrs M)	NWH ICU ICU289 A	—		—		—	*			None on file	None	—	—	—
Concern, Sicu (68yrs M)	NWH 4 USEN 4U457 A	—		—	—	—	*			None on file	None	—	—	—
Concern, Trans (79yrs M)	BWH 14D 75-1	—		—	—	—				None on file	None	—	—	—

CONCERN "App" Intervention



CONCERN Intervention: Configured Nurse Leader Quality Safety Dashboard



CONCERN Simulation Testing

- Evaluate the impact of CONCERN prototype on RN/MD shared situational awareness of patient's risk
  - Method: The Situation Awareness Global Assessment Technique (SAGAT)
    - "Freeze and Query"
      - Perception of the situation
      - Comprehension of the data presented in each prototype
      - Projection of the patient status in the near future
    - Compare responses between nurses and physicians

CONCERN: User-centered Design

Themes from nurse and physician interviews and simulation sessions

- Do not add interruptive alerts
  - Too many of these already
- Harmonize with existing information flow and workflow
  - Patient list
  - Unit dashboard
- Perceived concerns:
  - Every patient in ICU would be red or yellow
  - Potential increase in documentation
- Perceived usefulness for:
  - Handoff reporting
  - Prioritizing patient rounds
  - Helping new nurses prioritize patients
  - Helping float pool nurses assigned to round on units to prioritize
  - "Evidence" that backs up nurses' intuition with patient deterioration

Concern Specific Aims:

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- **Primary outcomes:** in-hospital mortality and length of stay
- **Secondary outcomes:** cardiac arrest, unanticipated transfers to the intensive care unit, and 30-day hospital readmission rates.

CONCERN Clinical Trial Research Questions

- Is the CONCERN app associated with improved patient outcomes?
  - Primary outcomes: In-hospital mortality, Length of stay
  - Secondary outcomes: Cardiac arrest, Unanticipated transfers to the intensive care unit, 30-day hospital readmission rates

Site/Setting

- BWH/NYP (Academic Medical Centers) and Newton-Wellesley/Allen Hospitals: Community Teaching Hospitals
  - Non specialty acute care
  - ICUs

Randomly assigned by healthcare system to intervention and control units

Hypothesis and Study Design

- CONCERN SMART App will be associated with decreased in-patient mortality, length of stay, and 30-day hospital readmission rates across two hospital systems compared to current state.
- Cluster randomized design (units within health system)

Study Arm	Site	Pre-intervention (6 months)	XXX	Phase 1 (9 months) [Intervention]	XXX	Phase 2 (3 months)
Control Groups	BWH MIL	B		Silent		Silent
	NWH ALN	B		Silent		Silent
Intervention Groups	BWH MIL	B		Active		Silent
	NWH ALN	B		Active		Silent

B = Baseline data

Silent = CONCERN App will function but will not display to clinician

Active = CONCERN App will display to clinician.

CONCERN Pocket Card

BRIGHAM HEALTH
BRIGHAM AND WOMEN'S HOSPITAL

CONCERN SmartApp

An Epic-integrated Clinical Decision Support Tool

NEWTON-WELLESLEY HOSPITAL

Communicating **N**arrative **C**oncerns **E**ntered by **RN**s

About CONCERN: The CONCERN algorithm predicts patient decline based on nursing documentation.

CONCERN Levels

Calculated every hour

Intervention Units

- = High: "Showing signs of deterioration"
- = Medium: "Risk for deterioration"
- = Low: "Low risk for deterioration"
- * = "New Result"

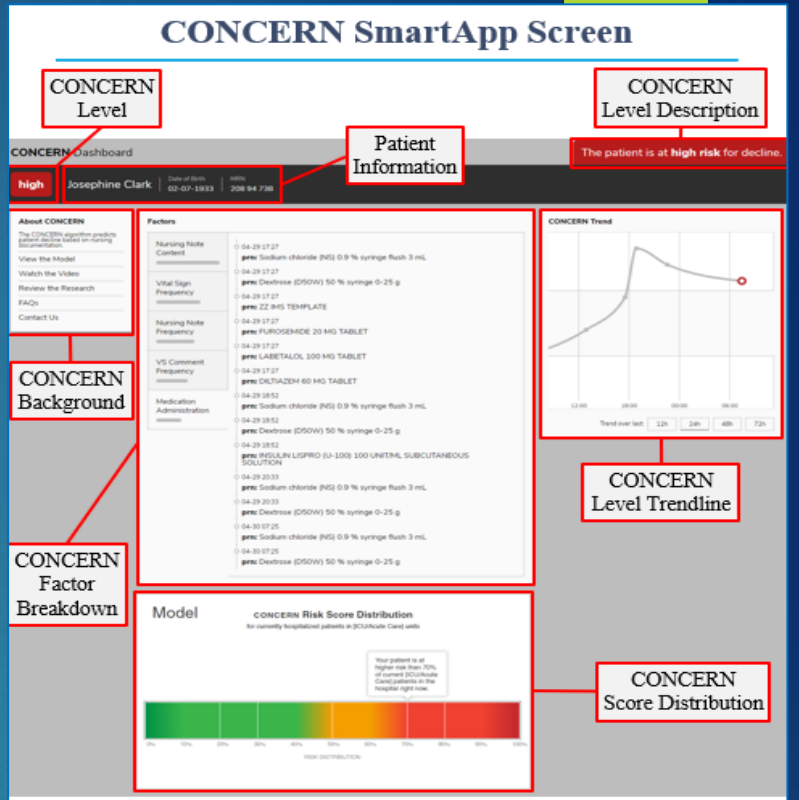
Control Units

- = Null: "Risk for deterioration has not been calculated"

Double-clicking on the colored icons in the Patient List will open the CONCERN SmartApp

concernstudy@partners.org

CONCERN SmartApp Screen



CONCERN Level Driving Factors

- **Nursing Note Content**: Examples of concerning phrases: "MD aware", "EKG obtained"
- **Medication Administration**: Frequency of PRNs given, medications withheld
- **Vital Sign Frequency**: Frequency of vital signs entered
- **VS Comment Frequency**: Frequency of vital sign comments entered
- **Nursing Note Frequency**: Frequency of nursing notes entered

concernstudy@partners.org

CONCERN Training Poster

BRIGHAM HEALTH
BRIGHAM AND WOMEN'S HOSPITAL

CONCERN SmartApp

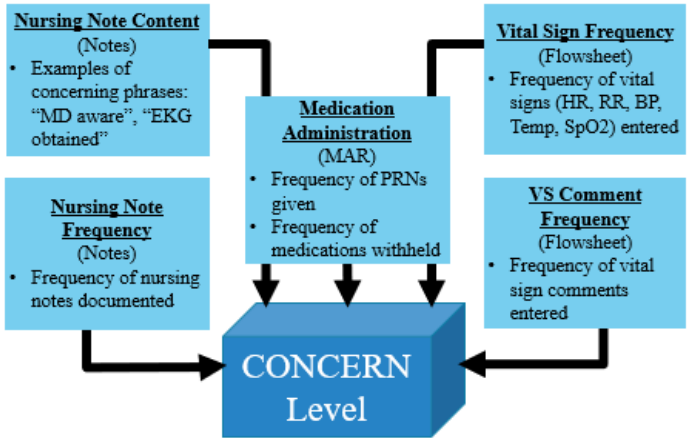
An Epic-integrated Clinical Decision Support Tool

NEWTON-WELLESLEY HOSPITAL

About CONCERN (**C**ommunicating **N**arrative **C**oncerns **E**ntered by **RN**s): The CONCERN algorithm predicts patient decline based on nursing documentation.

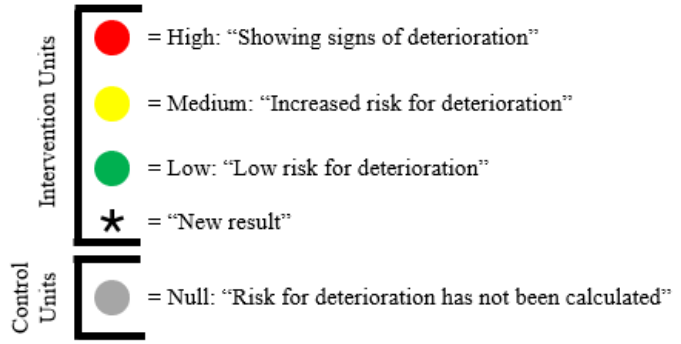
What drives the CONCERN Level?

Calculated from the previous 24 hours

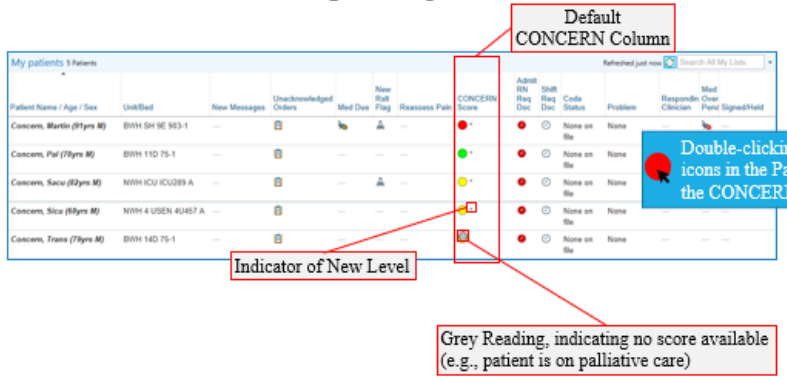


CONCERN Levels

Calculated every hour

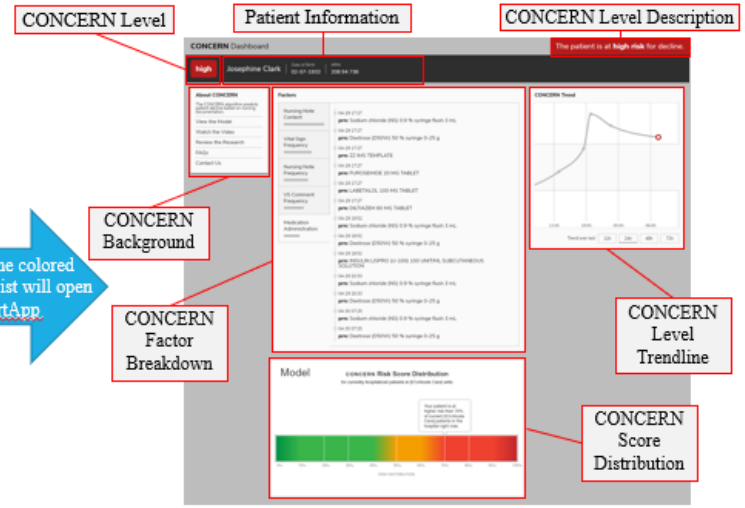


CONCERN-integrated Epic Patient List



Double-clicking on the colored icons in the Patient List will open the CONCERN SmartApp

CONCERN SmartApp Screen



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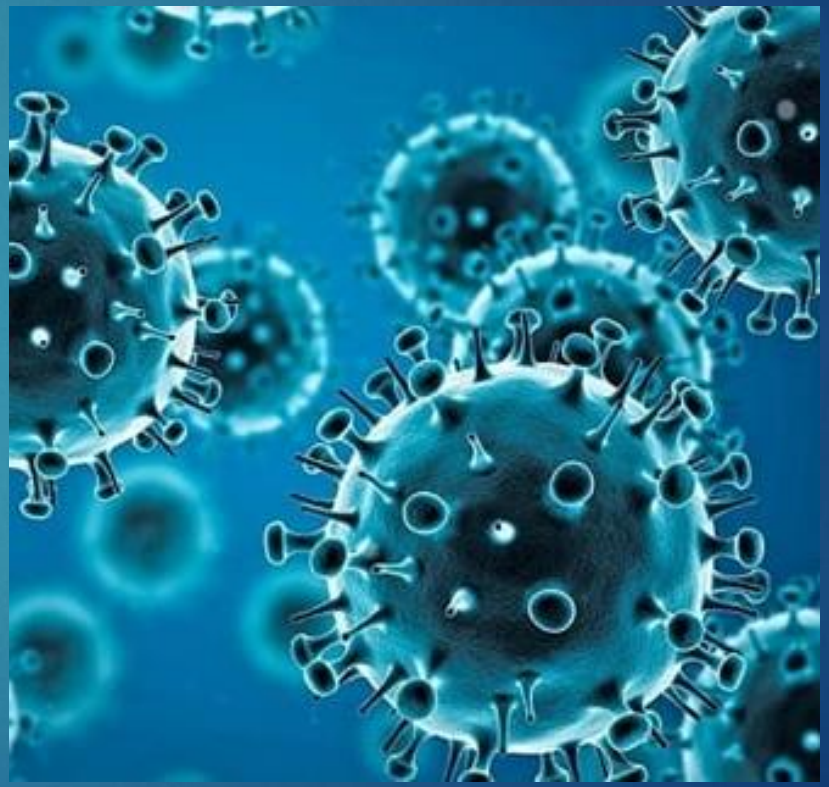
Implementation Challenges

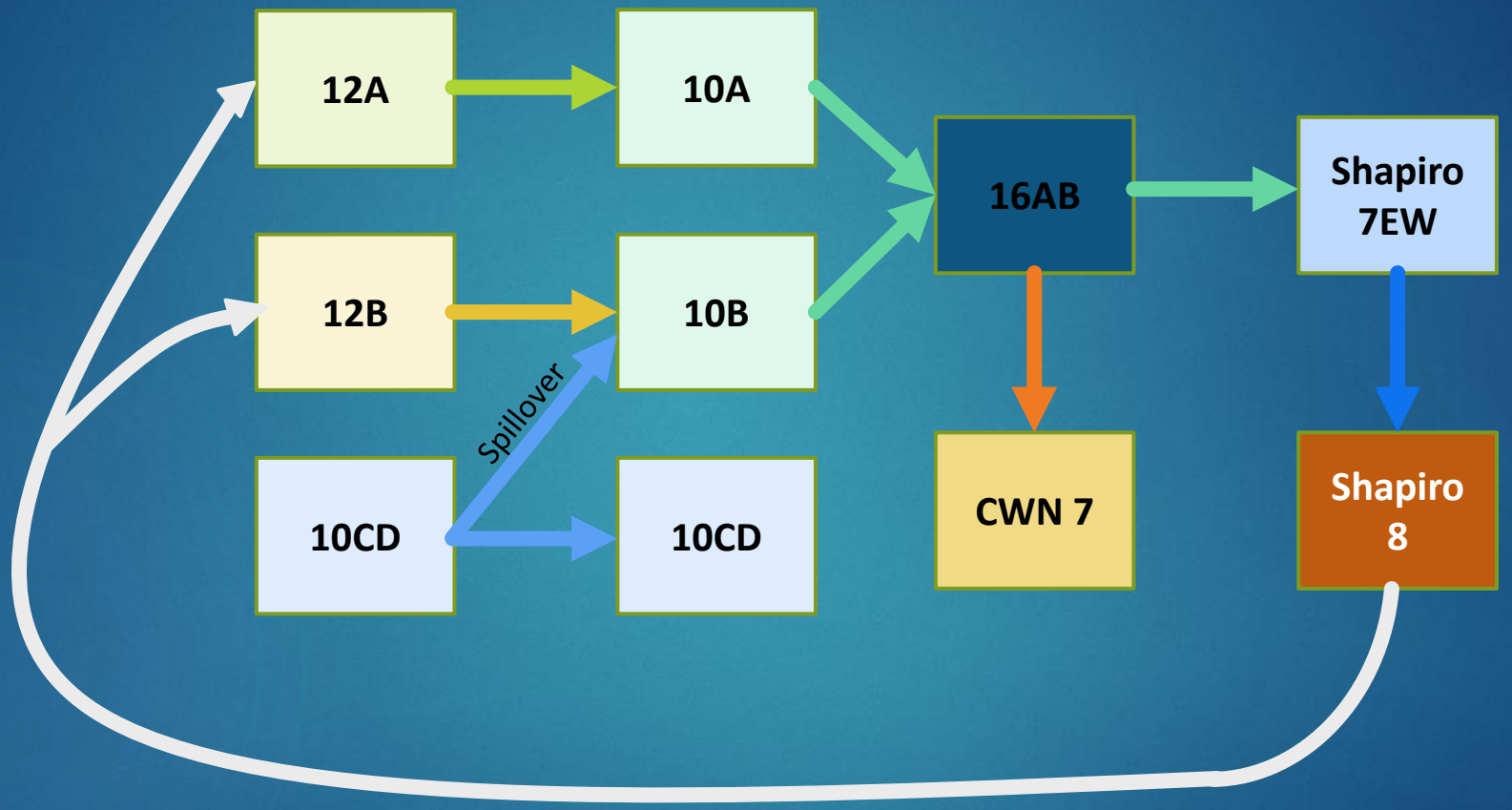
- COVID!!!
  - Timelines
  - Unit movement
- eCare integration
  - Different EPIC configurations

Impact of COVID 19 Public Health Emergency on CONCERN Research and Implementation

- COVID-19 pandemic highlighted deficiencies in public health and research infrastructures
- Federal research funding diverted to COVID-19 related clinical trials
  - Approximately 80% of non-COVID-19 clinical trials were stopped or interrupted
- Widespread efforts to minimize COVID-19 transmission
  - Healthcare facilities closed their doors to "nonessential" services
- Stopped or limited research activities
  - Researchers largely became remote workers
  - Restrictions impacted data collection, monitoring, and other protocol-related requirements



Unit Movements—Convolution, Visualized

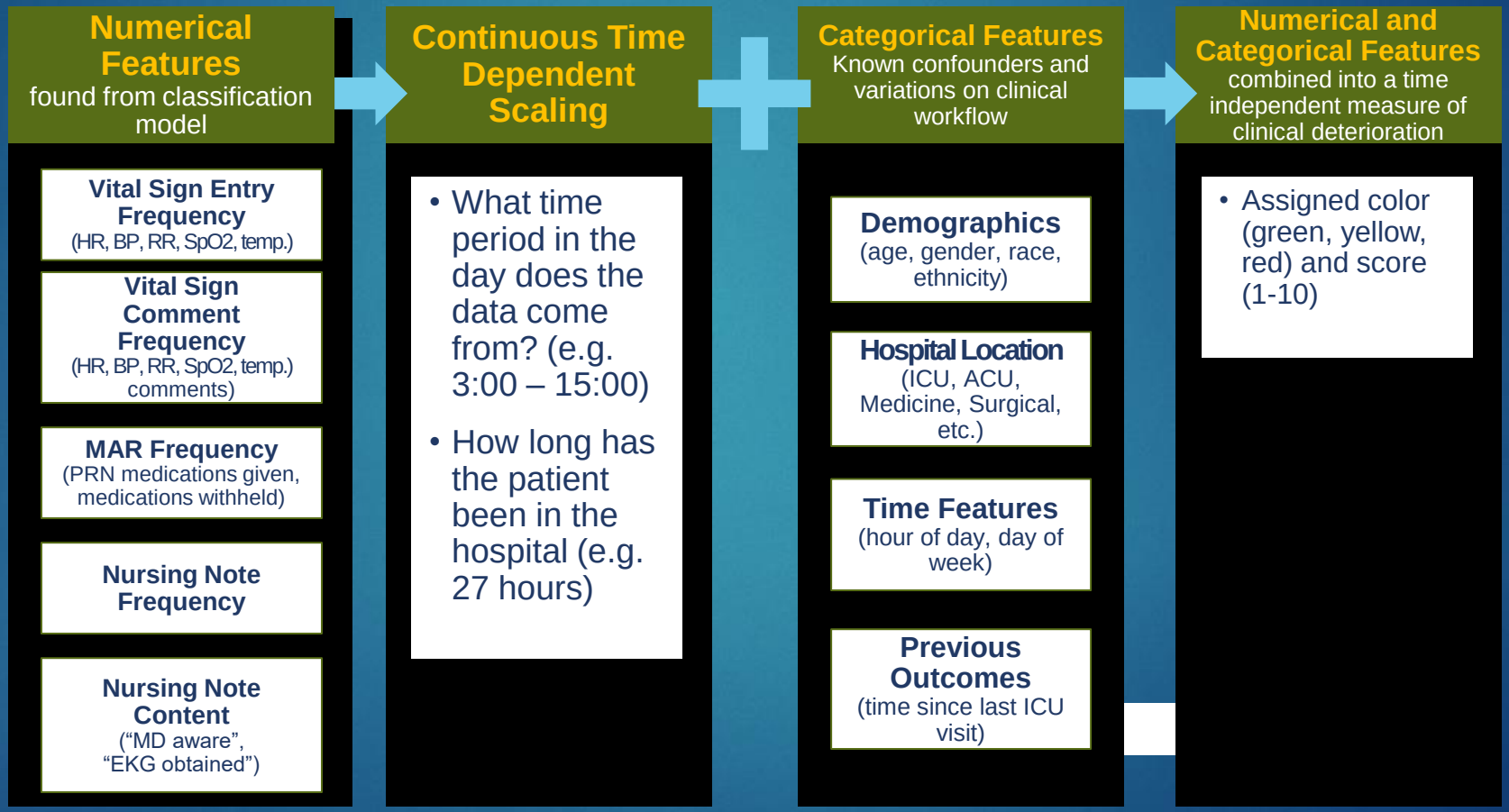


- Spring 2020 Forward: High influx of COVID-19 hospitalizations, BWH performed frequent location changes of several units/ services
- Movements were considered "temporary" in response to adapting care and census requirements

EHR integration and Configuration Options

Components	Options	Purpose
CONCERN Decision Engine	FHIR web services Interface Epic web services	Get patient/unit data for prediction Write CONCERN score and related info to flowsheet
CONCERN Dashboard	FHIR web services Interface Epic web services	Pull patient data Write user interaction
Patient list	In Epic	See CONCERN risk level

The CONCERN Back-End Engine (Using FHIR)



Discussion

- Previous studies suggest a linkage between nursing documentation patterns and patient status
- Nursing data is BIG data--- methods are needed for processing and analysis (quantitative and qualitative)
  - Methods are needed for "unlocking" documentation patterns and unstructured data from nursing documentation
- Healthcare Process Modeling uses metadata patterns that reflect nurse expert decision making
  - Clinically significant improved led time for patient deterioration
- Leveraging domain expertise is essential for accurate modeling
  - Processing & analyzing clinical data
  - Translating predictive models for CDS design
  - CDS implementation
- CONCERN will enable early identification of at-risk patients for implementation in clinical decision support

Next Steps:

- Evaluate clinical trial results for the impact of the CONCERN SmartApp on patient outcomes at both sites
- Perform deeper investigation of nursing and interprofessional communication patterns discoverable from the EHR in relation to hospitalized patients at risk of decompensation
- Openly share a de-identified version of our CONCERN data set
- American Nursing Foundation Grant to Spread to other hospitals/healthcare systems:
  - MGB: Additional sites
  - Vanderbilt Univ Medical Center
  - Washington Univ Medical Center, St. Louis

CONCERN Team

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(NINR): 1R01NR016941-01: Communicating Narrative Concerns Entered by RNs (CONCERN): Clinical Decision Support Communication for Risky Patient States.

Thank You!

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