Multi-state Modeling of Pressure Injury Staging Transition Trajectories

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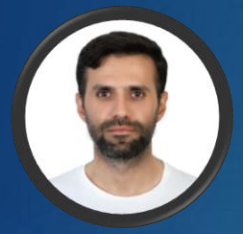
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Overview

- Background: Opportunities and challenges related to pressure injury prevention in acute care settings
- Overcoming Challenges: Multi-state Modeling of Pressure Injury Staging Transition Trajectories
- Discussion/Conclusions

Pressure Injury Prevention

Why important patient safety issue?

- Pressure injuries (PrIs) are "a volume, high-cost condition".
  - ~10% of hospitalized patients affected by PrIs.
  - Majority of PrIs are preventable.
  - Increases morbidity, mortality and decreases quality of life.
  - Annual financial burden : 28.2 billion (USD, 2019).

What gap are we addressing?

- The National Pressure Injury Advisory Panel pressure injury (PrI) staging system:
  - Stage I, II, III, IV, unstageable, and deep tissue pressure injury (DTPI)
- Dynamic PrI stage transition patterns can inform evaluation and treatment.
- Limited research exploring the underlying mechanism of stage transitions and related driving factors.

What are the Limitations of Existing Machine Learning Methods for Processing Pressure Injury Data?

- Lack of temporal features included in existing machine learning models.
- Rarely include dynamic changes in daily nursing assessments which may contain important time-sensitive patterns to improve risk prediction.
- When nursing assessments are included, the data from a single time point, e.g., single value documented prior to occurrence of PrI in cases and the single value documented prior to discharge in controls.
  - Results in a loss and bias of important information on patient's status, especially regarding temporal changes.

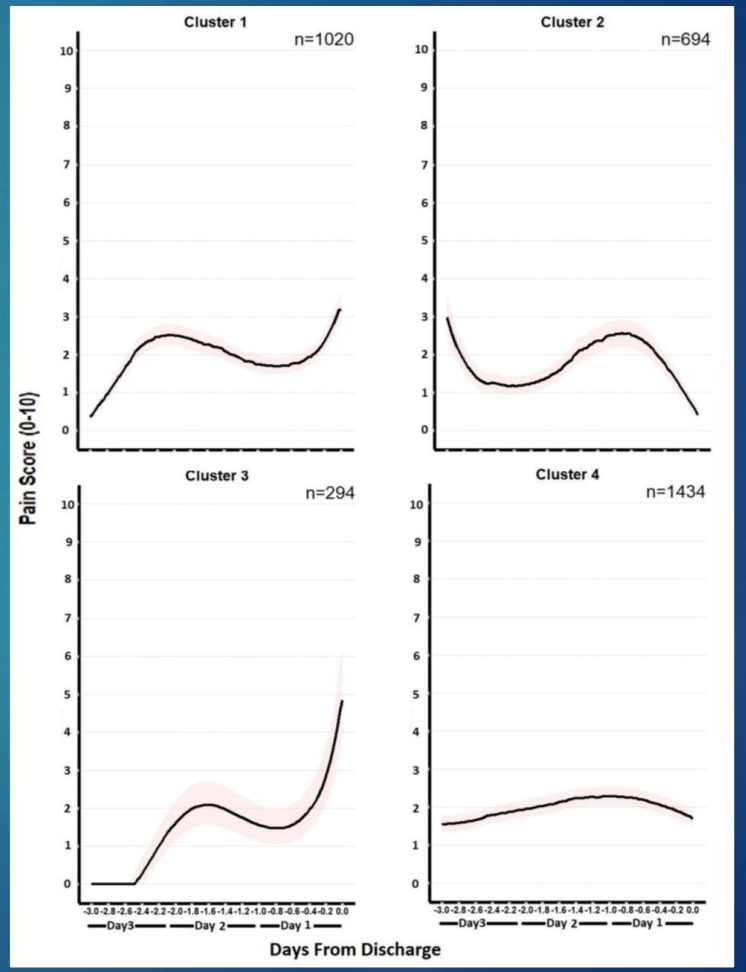
Use of Electronic Health Record Data and Trajectory Analysis for Timely Identification and Diagnosis of Deep Tissue Injury

- *Project Goal:* To develop a comprehensive set of severe pressure injury risk factors and compare its prediction accuracy to the Braden Scale.
  - To explore the potential value of the Braden Scale and its subcomponents in predicting dynamic PrI stage transition patterns.
- *Cohort:* Patients aged 18 and older and admitted to Mass General Brigham Intensive Care Unit (ICU) and Non-ICU units.

Trajectory Analysis for Dynamic Clinical Conditions

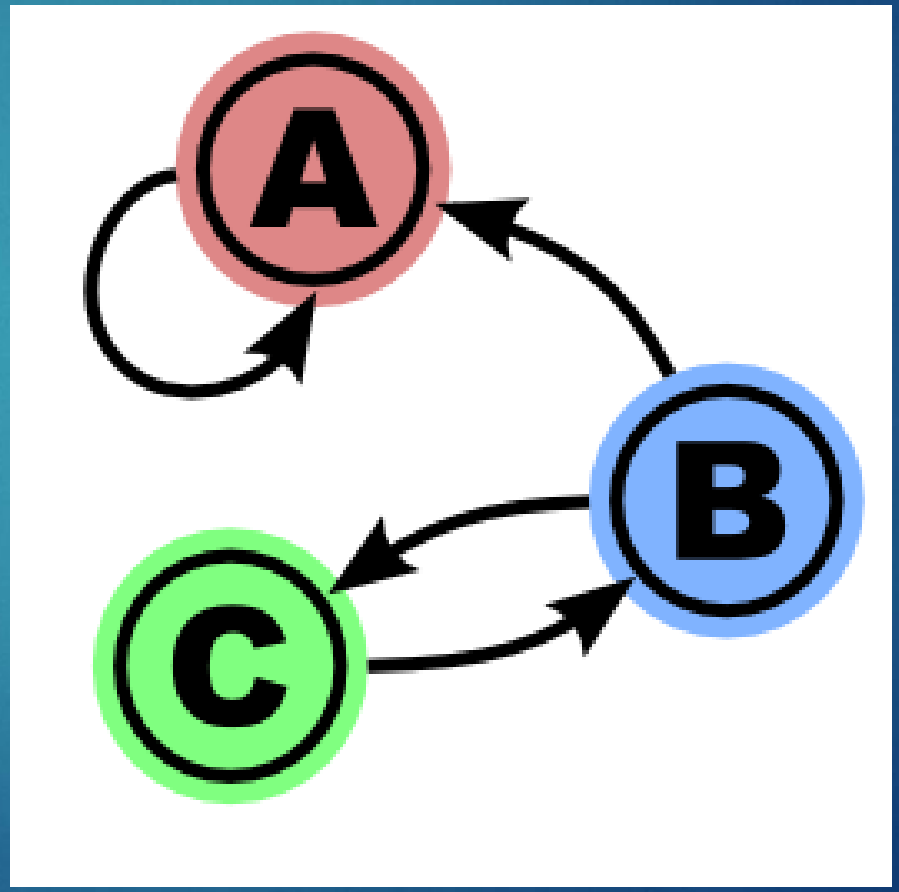
Example of Trajectory Analysis from Weng et.al. 2020

- Advantages of Trajectory Analysis:
  - In the real world, most clinical conditions are time sensitive with different progression stages.
  - Reflects dynamic patterns of patient condition and categorizes distinct trajectory groups or their association with risk levels.

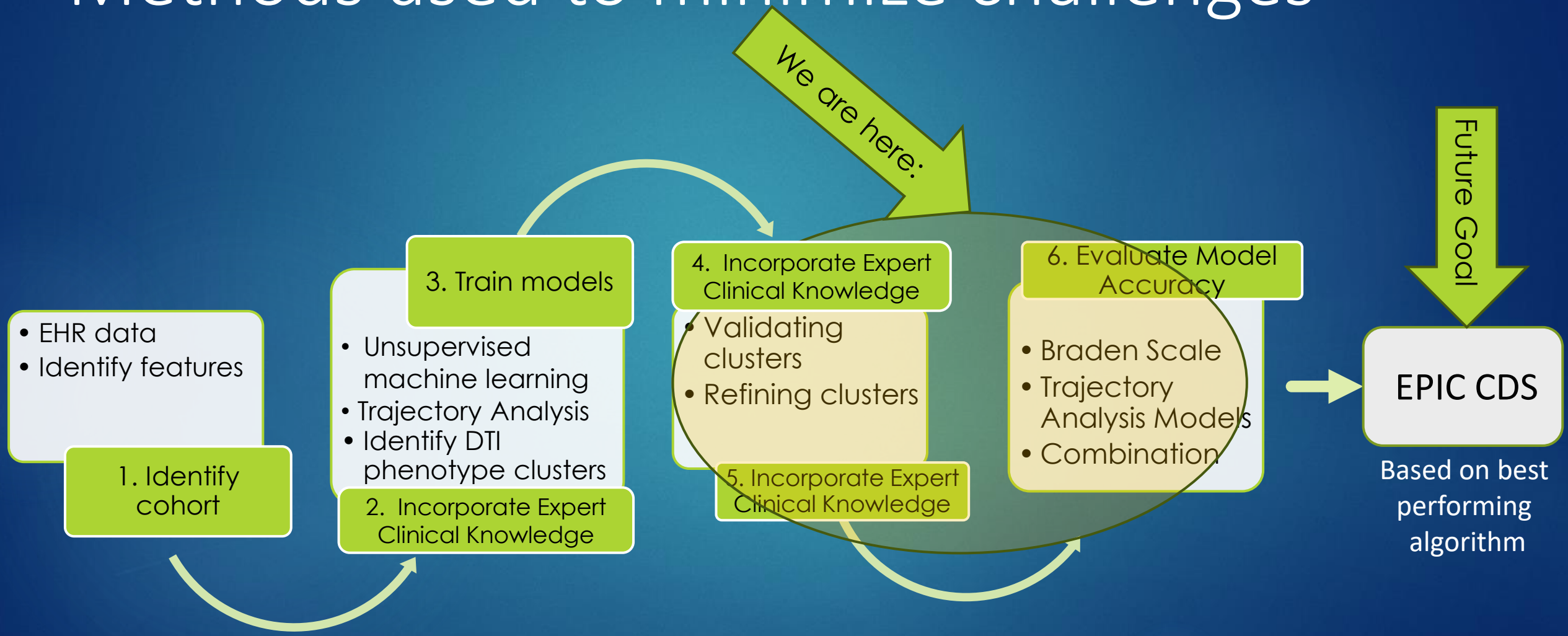


Methods: What did we do?

- Used Markov multi-state modeling to evaluate the time-sensitive progression trajectory of pressure injury stages based on real-world electronic health record (EHR) datasets.
  - Extracted PrI records including stage measure values and the time of injury occurrence from nursing flowsheets from across 5 hospitals (2015 to 2023).
  - Used a continuous-time multi-state model to estimate transition intensities between 3 pressure injury states: stage 1, 2 and severe stage (including stage 3, 4 or unstageable).
  - Model input: Defined multiple rules for data cleaning steps and stage transitions based on NPIAP guidelines and expert opinion.



Methods used to minimize challenges



Results: What did we find?

Number of patients in the dataset (2015-2023): 29,475

Total number of pressure injuries after data cleaning/exclusions applied: 3474

Number of pressure injuries per location:

Coccyx
- 1342 (38.6%)

Buttocks
- 1085 (31.2%)

Sacrum
612 (17.6%)

Heel
- 435 (12.5%)

Results: What did we find?

- Within each PrI location group, we further divided patients into 3 staging groups, including stage 1, 2, and severe stage (including stage 3, 4 and unstageable pressure injury).

Estimated Transition Intensities Between Pressure Injury Stages								
	Coccyx		Buttocks		Sacrum		Heel	
	Transition Intensity (%)	95% CI	Transition Intensity (%)	95% CI	Transition Intensity (%)	95% CI	Transition Intensity (%)	95% CI
Stage 1 to Stage 2	0.013	(0.011, 0.015)	0.010	(0.009, 0.012)	0.007	(0.005, 0.009)	0.008	(0.006, 0.010)
Stage 1 to Stage 3/4/Unstageable	0.004	(0.003, 0.005)	0.003	(0.002, 0.004)	0.004	(0.003, 0.007)	0.002	(0.001, 0.004)
Stage 2 to Stage 3/4/Unstageable	0.019	(0.016, 0.022)	0.016	(0.013, 0.019)	0.025	(0.018, 0.035)	0.024	(0.016, 0.036)

Discussion/Conclusions

- We developed a novel multi-state pressure injury trajectory model using real-world clinical records.
- Stage 2 seems to serve as a "gateway state" during the development trajectory to a severe stage pressure injury.
  - Once a patient progresses to stage 2, the likelihood of transiting to severe stages is much greater.
- We also observed location-dependent variations, suggesting location-specific interventions and treatments can be important for pressure injure management.

Thank You!

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