Recurrent Overdose Survival Modeling for Smarter Harm Reduction Deployment
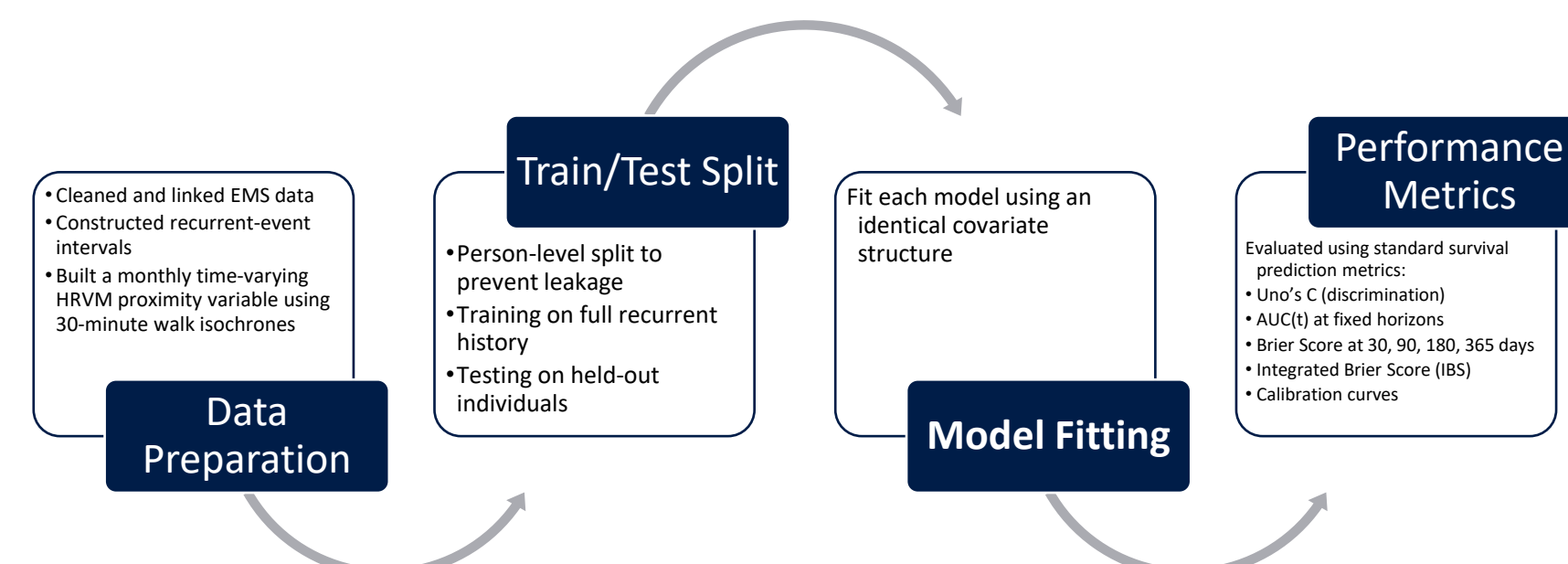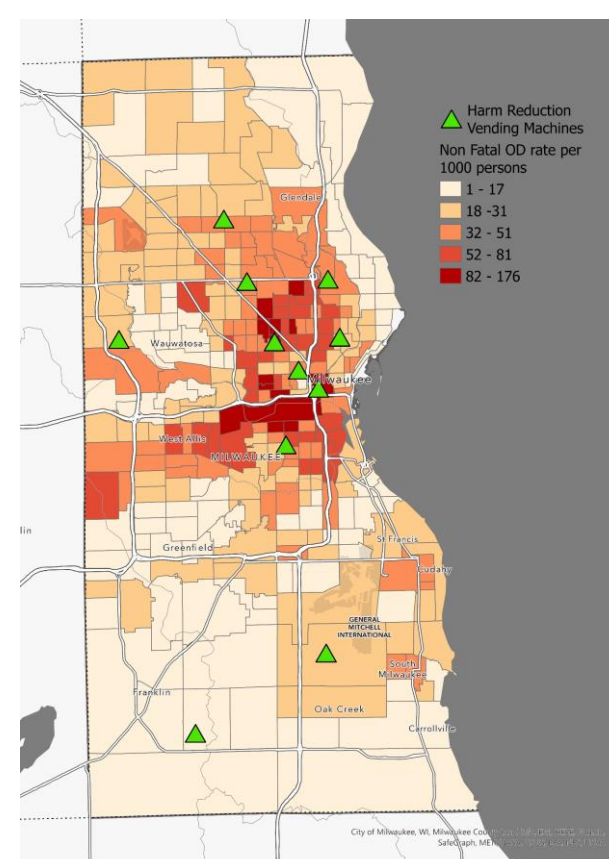
INTRODUCTION

- Individuals who survive a nonfatal overdose face a substantially elevated risk of subsequent and fatal overdose, yet most evaluations still treat overdoses as one-time events.
- Harm Reduction Vending Machines (HRVMs) provide 24/7, low-barrier access to naloxone and safer-use supplies, particularly for people not engaged in ongoing treatment or regular care.
- While HRVMs expand access, evidence is limited on whether they influence repeat overdose risk over time, which is the group at greatest clinical concern.
- This study examines whether structural access to HRVMs is associated with longer intervals between overdoses and improved survival trajectories, rather than changes in overdose counts alone.

METHODS

- Countywide evaluation of HRVMs in Milwaukee County using linked EMS nonfatal overdose records and Medical Examiner fatal overdose data from 2018–2023.

Population-level analysis: Interrupted time series compared overdose trends within and beyond 30-minute HRVM access areas
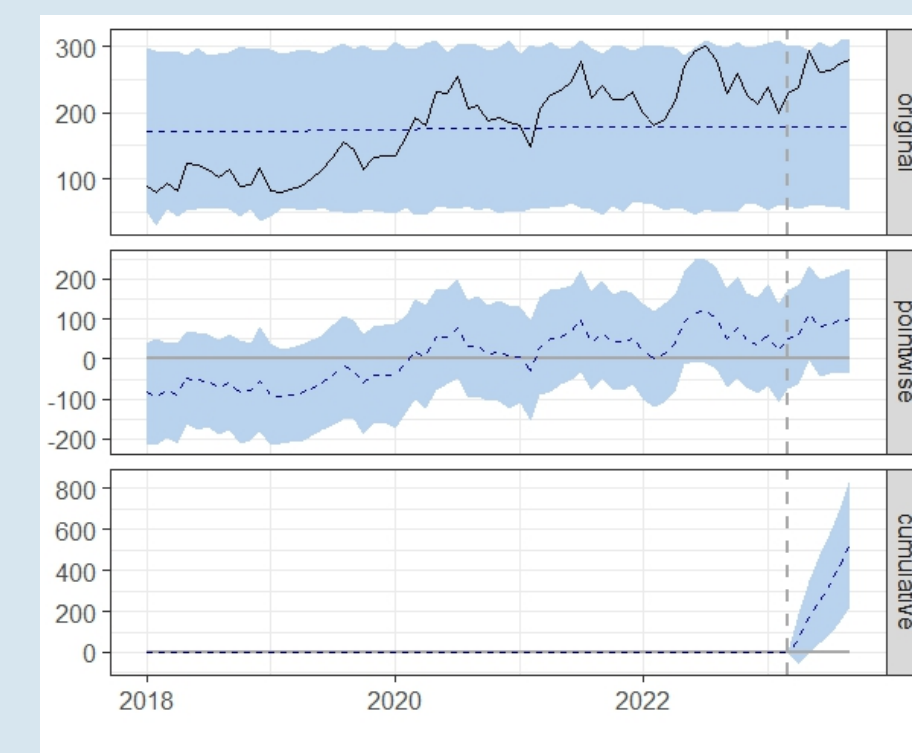
Individual-level analysis: Recurrent-event survival models estimated how HRVM proximity related to the time between overdoses, treating overdose as a repeating clinical risk rather than a single event.

Data Preparation
- Cleaned and linked EMS data
- Constructed recurrent-event intervals
- Built a monthly time-varying HRVM proximity variable using 30-minute walk isochrones

Train/Test Split
- Person-level split to prevent leakage
- Training on full recurrent history
- Testing on held-out individuals

Fit each model using an identical covariate structure

Model Fitting

Performance Metrics
- Evaluated using standard survival prediction metrics:
- Uno's C (discrimination)
- AUC(t) at fixed horizons
- Brier Score at 30, 90, 180, 365 days
- Integrated Brier Score (IBS)
- Calibration curves

RESULTS

Population level:
- Observed nonfatal overdoses exceeded counterfactual expectations after HRVM deployment, indicating a shift in county-level overdose dynamics.
- Within 30-minute access areas, post-intervention counts averaged 268.5 vs 179.8 expected, totaling 1.61K vs 1.08K nonfatal overdoses (+53%, 95% interval: +16% to +111%).
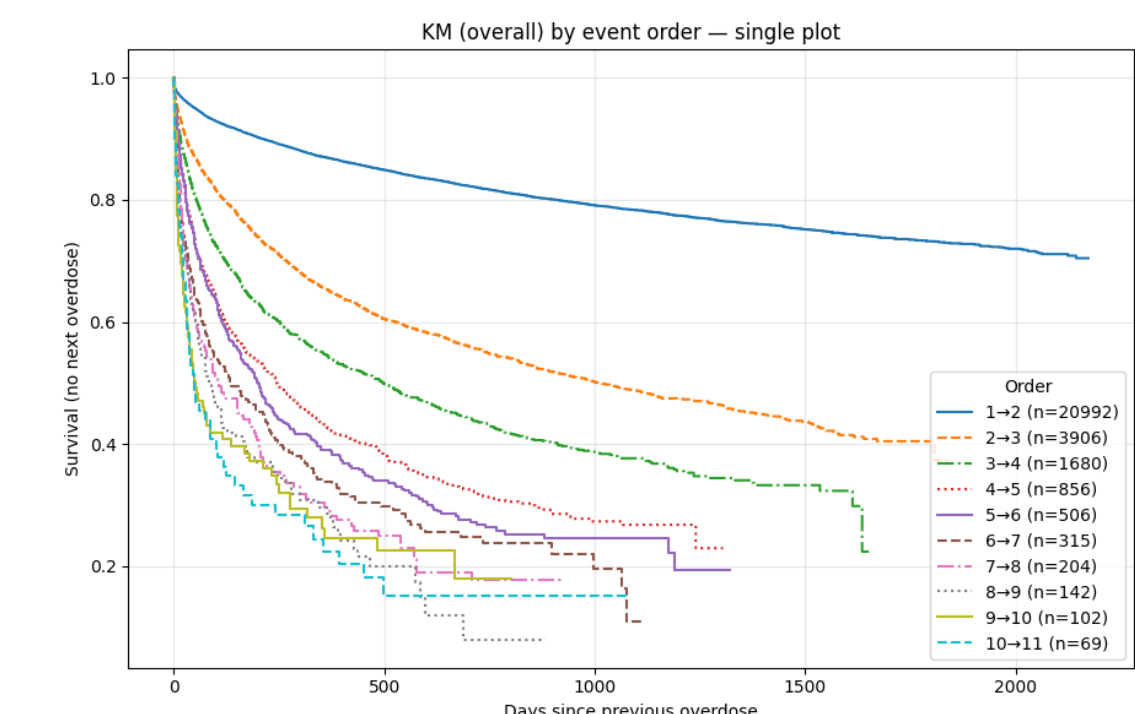

Individual level:
- Recurrent overdose was common, with 3,803 individuals accounting for over 40% of nonfatal overdoses (2018–2023).
- Recurrence risk was highest soon after an overdose and accelerated with each subsequent event, supporting recurrent-event modeling over single-event approaches.
- Contextual and system factors (e.g., scene type, EMS disposition) predicted rapid recurrence more strongly than proximity alone.
- While HRVM proximity showed no large adjusted hazard reduction, individuals within 30-minute access accumulated repeat overdoses more slowly over time.
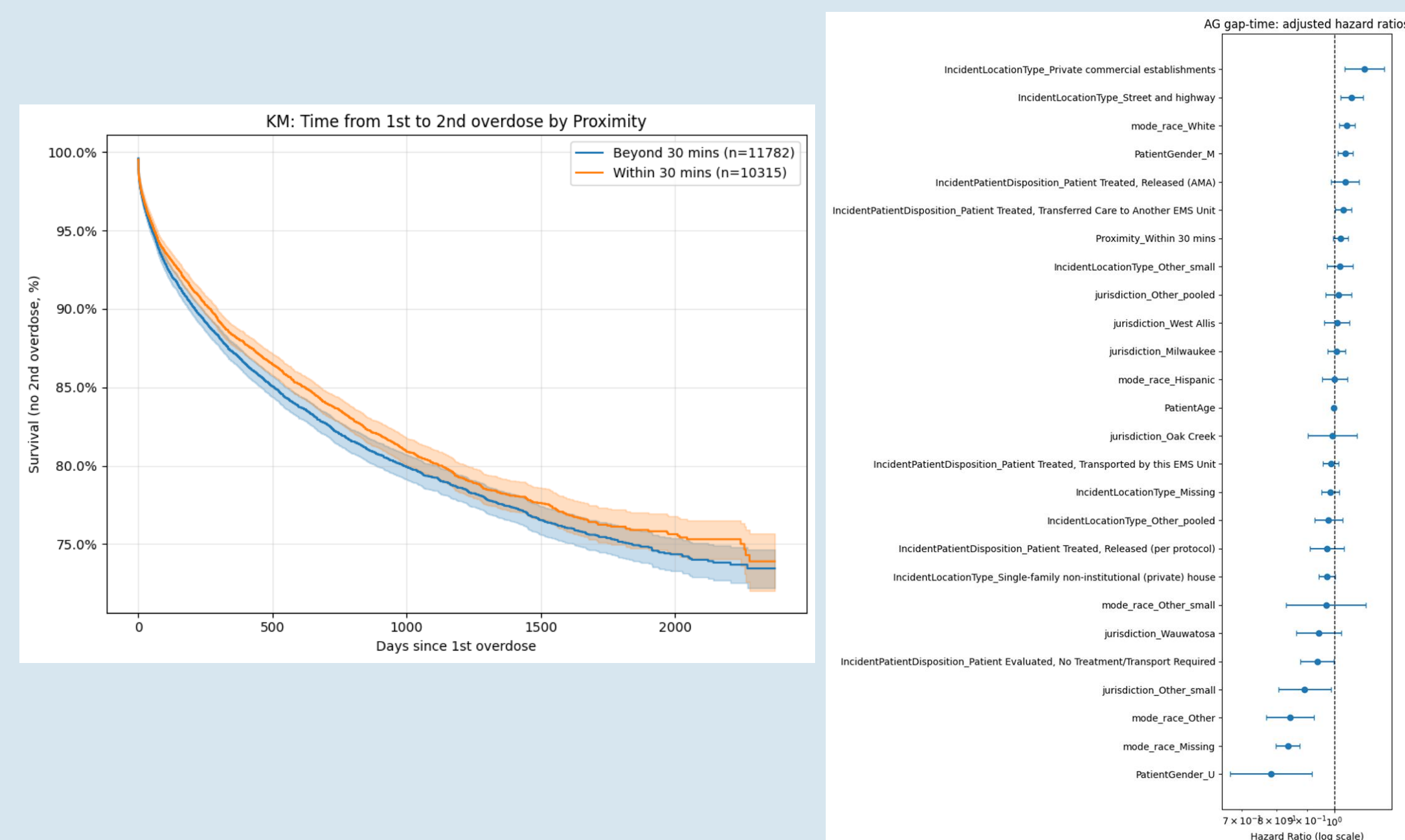
CONCLUSION

- Treating overdose as a recurrent condition revealed patterns missed by count-based analyses.
- Population trends showed increased nonfatal overdoses after HRVM deployment, while individual-level survival analyses demonstrated accelerating recurrence risk.
- Recurrent-event models outperformed single-event approaches, and contextual and system-level factors were stronger predictors of recurrence than proximity alone.
- HRVM exposure reflected access, not confirmed use, and the observational design limits causal inference.
- Evaluating harm reduction using recurrence- and survival-based metrics can better inform HRVM placement, EMS integration, and future intervention design.

AUTHORS & DISCLOSURES

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ACKNOWLEDGEMENT