Standard EWS evaluations pool observations across time, yielding misleading estimates of net benefit and utility. Our calendar-day framework provides clinically meaningful estimates.

A Clinically Intuitive Approach to Evaluate Performance of Early Warning Scores

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Introduction

Early Warning Scores (EWS): widely used to detect deterioration in hospitalized patients.[1-4]

Evaluation Metrics: Discrimination (e.g., AUC) do not reflect clinical trade-offs of benefit vs. harm; Net benefit and utility better capture clinical impact.[5]

Problem: Standard evaluations pool observations across years, assuming patients who are NOT hospitalized together share the same care resources.

→ misleading estimates of net benefit and utility.

Objective: Propose a new calendar-day framework that evaluates patients hospitalized concurrently, yielding realistic and clinically meaningful estimates of net benefit and utility.

Methods: Data & Framework

Data: Retrospective cohort of adult hospital admissions, University of Chicago (2009–2020); split into derivation (2009–2014) and internal validation (2015–2020) cohorts.

EWS Models: MEWS, NEWS, Logistic Regression (LogReg), Recurrent Neural Network (RNN), XGBoost (XGB).

Outcome: Clinical deterioration (unplanned ICU transfer or death within 24h).

Evaluation Framework

Standard pooling: All observations combined to get net benefit and utility.

Calendar-day evaluation:

- Patients present at 8 AM each calendar day (concurrent daily cohorts). See Figure 1.
- Outcomes are determined within the following 24h.
- Net benefit and utility are represented as median (IQR) across daily estimates.

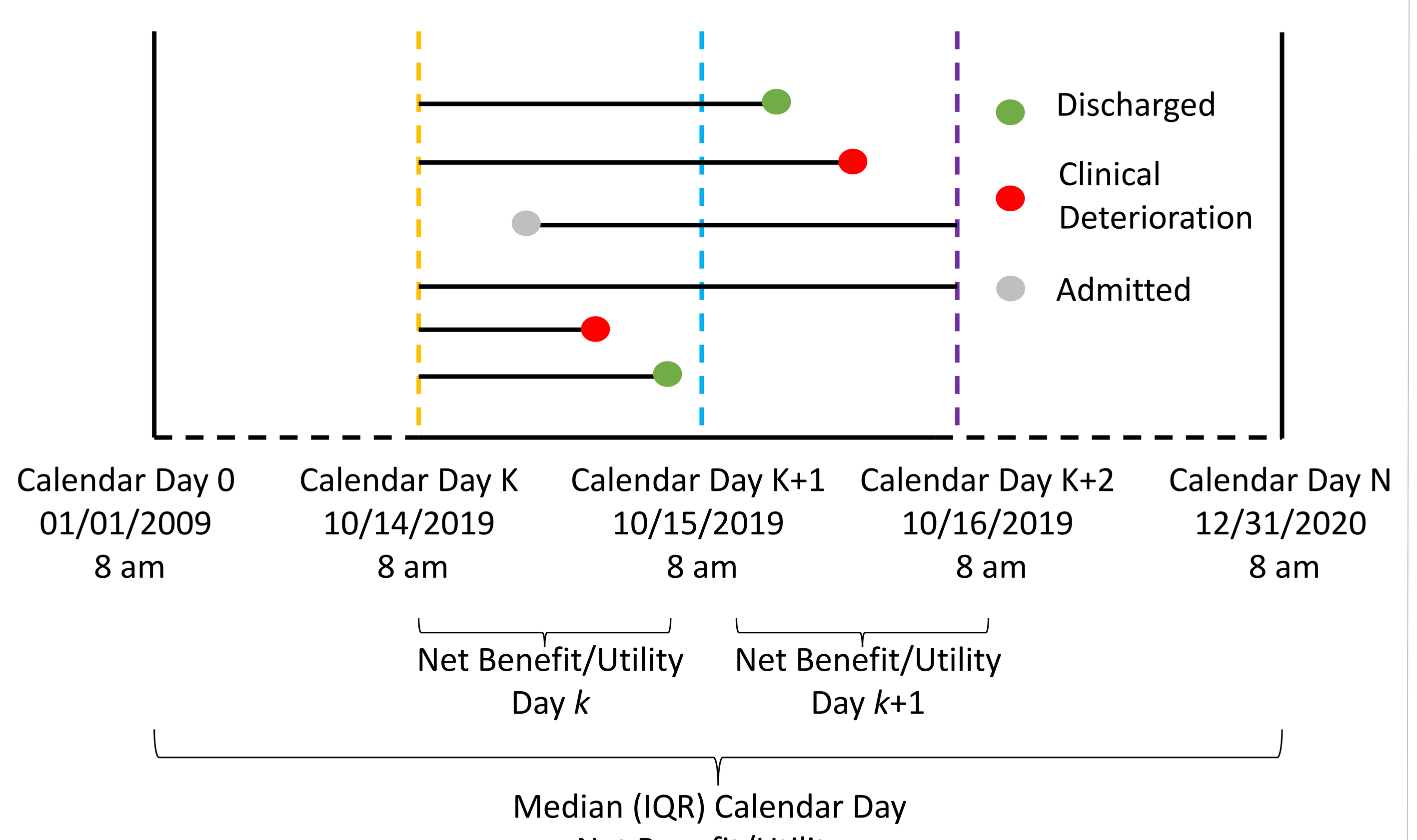


Figure 1. Illustration of calendar-day net benefit/utility at 8 AM.

Methods: Metrics

Metrics:

- Net Benefit: decision-analytic benefit vs. harm.
- Utility: assigning different costs to all four prediction results (see Figure 2).

Figure 2. Confusion matrix with cost values for utility evaluation.

	Patient deteriorates	Patient stable
EWS predicts deterioration	**True Positive (TP)** Flagged deteriorating (cost = **-20**, to reflect harm of recognized decline)	**False Positive (FP)** Incorrectly flagged (cost = **-1**, to reflect minor burden of manual checking and possible testing)
EWS predicts **no** deterioration	**False Negative (FN)** Missed deteriorating (cost = **-40**, to reflect harm associated with missed recognition of decline)	**True Negative (TN)** Correctly unflagged (cost = **0**, to reflect the cost of stable hospitalized patient)

Results

Study Population: Of 363,199 hospitalized patients, 16,826 (4.6%) experienced clinical deterioration.

Net Benefit:

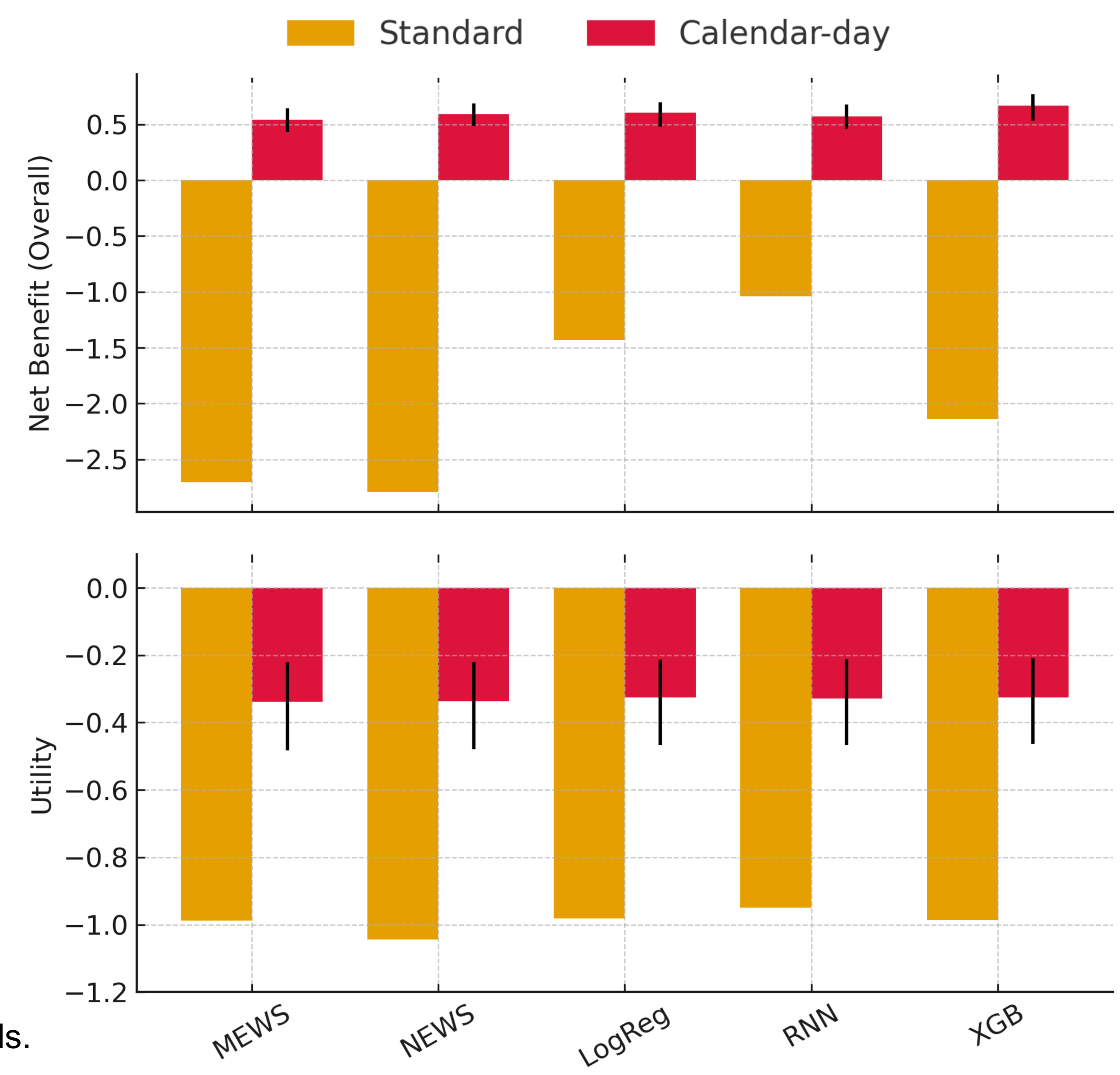
- Under the **standard pooling approach**, overall net benefits are low (–1.039 to –2.794).
- With the **calendar-day framework**, all EWS models showed **higher overall net benefit.**

Utility:

- Penalizing missed detection (FN) more heavily.
  - → Better reflects hospital priorities.
  - → Interpretable and clinically realistic.
- Calendar-day utility values of all EWS models were higher than their standard counterparts.

Best Performer: XGB achieved the highest calendar-day net benefit and utility, significantly outperforming other EWS models.

Figure 3. Comparison of standard and calendar-day net benefit and utility.



Conclusions

- Standard evaluation methods **pool across non-overlapping hospitalizations**, producing implausible or misleading net benefit values.
- Our **calendar-day framework** provides higher estimates of net benefit and clinical utility by evaluating patients hospitalized concurrently.
- **Clinical utility**, which allows for allocating greater harm to missed deterioration, better reflects hospital priorities than net benefit alone.
- **XGB** achieved the highest calendar-day net benefit and utility.
- Our framework facilitates better estimation of EWS impact during validation.

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