

Observability of Fifth Universal Definition of Myocardial Infarction components in linked electronic health records: a retrospective MIMIC-IV study

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Abstract

Background

Clinical definitions can be operationalised from routine data only when the required evidence is represented, linked, and available at the intended decision time. We assessed the fitness of linked electronic health record (EHR) data for retrospective evaluation of Fifth Universal Definition of Myocardial Infarction (UDMI) components.

Methods

This retrospective data-field audit included 6189 adults in MIMIC-IV with a pragmatic dynamic troponin T pattern above an available local upper reference limit during an estimated 2008–2019 care period. The primary analysis mapped required definition components to linked sources and quantified component-specific operational observability. Symptom and machine-electrocardiogram (ECG) evidence were anchored to 1 hour before to < 2 hours after emergency-department arrival, and ECG status was represented as positive, negative, or unavailable. Mortality models were secondary and descriptive; eICU was used only for a portability audit.

Results

The pragmatic troponin rule and chief-complaint field were observable for all 6189 patients but were only partial proxies for the corresponding definition components. A linked ECG report was available in the strict window for 4911 patients (79.4%); 1278 (20.6%) had no linked report. Sex-specific upper reference limits, systematic time-locked imaging, thrombus evidence, mechanism adjudication, and procedure-related myocardial infarction adjudication were unavailable. Captured symptom-or-machine-ECG evidence was present in 1479 patients, whereas 4710 had neither captured source. ECG status was positive in 208 patients and negative in 4703. Standardised mortality was 14.72% and 10.54%, respectively (risk difference + 4.18 percentage points, 95% confidence interval – 0.80 to + 9.16).

Conclusions

Historical EHR fields supported only partial retrospective evaluation of Fifth-UDMI components. Source- and time-aware observability auditing exposed missing inputs and distinguished an unavailable record from a negative finding. The audit did not establish diagnosis, clinician action, or care quality. Local prospective source verification and human review are required before clinical implementation.

Background

Cardiac troponin establishes myocardial injury, not its cause. The Fifth Universal Definition of Myocardial Infarction (UDMI) requires a rise and/or fall in cardiac troponin with at least one value above the assay- and sex-specific 99th-percentile upper reference limit (URL) and, for myocardial infarction (MI), evidence of acute ischaemia. It also distinguishes MI mechanisms and procedure-related events and cautions that no single finding or universal troponin delta establishes the diagnosis [1].

Applying this framework at the emergency-department (ED)–acute-care interface requires integration of laboratory trajectories, symptoms, electrocardiograms (ECGs), imaging, angiographic findings, procedures, and clinical interpretation. Sepsis, hypoxaemia, hypotension, tachyarrhythmia, heart failure, pulmonary embolism, anaemia, and renal dysfunction may coexist with coronary disease or cause non-ischaemic injury. Diagnostic uncertainty and adverse outcomes persist across myocardial-injury and MI categories [2, 3]; systematic imaging can reclassify provisional diagnoses [4], and increasingly sensitive troponin reporting enlarges the population needing contextual interpretation [5].

EHR research adds a second problem: clinical evidence is distributed across sources that differ in provenance, timing, linkage, and completeness. EHR data quality is task dependent, and established frameworks distinguish dimensions such as completeness, conformance, plausibility, correctness, concordance, and currency [23, 24]. Multimodal phenotyping may improve cohort identification [6], but an absent database signal may indicate true absence, an unperformed test, delayed documentation, incomplete module coverage, failed linkage, or an extraction error. Treating these states as equivalent can convert a data-availability problem into an apparently clinical label. Before a definition is operationalised, each required component should therefore be mapped to its source, time window, observable state, and residual interpretation gap.

We used the Fifth UDMI as a data-requirements framework to audit retrospective component observability in linked MIMIC-IV records from ED encounters with dynamic troponin elevation above an available local URL. We prespecified a strict early-encounter window, source decomposition, and a three-state representation of ECG data; mortality associations were secondary descriptive context. A multimodal-selected cohort and selection weighting were sensitivity analyses. eICU was used only to assess portability of the field requirements to a database with different modalities. Unlike diagnostic phenotyping studies, this audit asks whether a clinical definition's required inputs are represented, linked, time aligned, and semantically adequate; that framework can be applied to other institutions, disease definitions, and decision-support use cases. We did not estimate diagnostic accuracy, evaluate care quality, classify MI mechanism, or infer treatment effects.

Methods

Study design, data sources, and reporting

This retrospective EHR data-field audit used locally hosted, deidentified MIMIC-IV version 3.1, MIMIC-IV-ED version 2.2, MIMIC-IV-Note version 2.2, MIMIC-IV-ECG version 1.0, and eICU Collaborative Research

Database version 2.0. MIMIC linked hospital, ED, discharge-note, and diagnostic-ECG modules; eICU supplied structured laboratory, diagnosis, treatment, APACHE, and hospital data [7–11]. The databases were created under their custodians' approvals and waivers and were accessed under PhysioNet data-use agreements. Reporting followed STROBE and RECORD [12, 13]. The estimated 2008–2019 care period preceded publication of the 2026 Fifth UDMI; the study therefore does not test contemporaneous guideline implementation, clinician behaviour, or care quality.

The Fifth UDMI supplied the requirements framework, not a clinical reference standard. MIMIC provided an available local URL rather than a frozen assay-, platform-, and sex-specific 99th percentile. Manual chart, ECG, imaging, and angiographic adjudication were not performed. We therefore report dynamic troponin elevation and captured MI-related evidence, not Fifth-UDMI-defined acute myocardial injury or clinically adjudicated infarction.

Study objectives and analysis hierarchy

The primary objective was to determine which Fifth-UDMI information components were observable in linked historical EHR data at the required source and time. The primary audit outcomes were the support category (supported, partially supported, unavailable, not operationalised, or not adjudicable), operationally observable count and proportion, and residual interpretation gap for each component. Source decomposition and three-state ECG availability were prespecified secondary audit analyses. Mortality associations were secondary descriptive context; selection analyses and alternate time or phrase definitions were sensitivity analyses; recorded-sex and calendar-period interactions, prediction analyses, and the eICU comparison were exploratory or portability analyses. No analysis was intended to estimate diagnostic accuracy, treatment effects, or quality of care.

MIMIC cohort and source-time framework

Index time was ED arrival. Adults required at least two numeric cardiac troponin T results from 6 hours before to 24 hours after arrival and at least one value above the available URL. Among adults with at least one qualifying selected-troponin series, the earliest encounter by index time was retained first, making the person-index encounter the unit of analysis. ED source, a pragmatic dynamic pattern (> 20% maximum change from the first value when the first value exceeded the URL and > 50% otherwise), and the common 2008–2019 module-era restriction were then applied. These prespecified thresholds defined a broad historical audit denominator; they were not diagnostic cut-points or Fifth-UDMI delta criteria. All 6189 eligible encounters formed the primary audit cohort. A 5412-encounter multimodal subset additionally required early-note and reference-note flags and broad acute-phase ECG availability within a legacy – 6/+12-hour window; this subset was used only in sensitivity analyses requiring those variables.

The primary information construct was captured symptom-or-machine-ECG evidence. Symptom evidence was an ED chief complaint containing chest pain, pressure, tightness, angina, or substernal wording. Machine-ECG evidence was a report containing STEMI, NSTEMI, acute infarction, 'consider acute infarct', or acute ST-elevation MI from 1 hour before to < 2 hours after arrival. Neither captured source meant that neither prespecified signal was observed. This group could contain an available machine report without a positive phrase or no linked report in the strict window; ECG unavailability was not interpreted as a negative ECG. We decomposed the union into symptom only, ECG only, both, and neither captured source and separately represented ECG status as positive, negative, or unavailable. Candidate timing, machine-phrase frequencies, exclusion of reports containing 'consider acute infarct', a + 2 to < + 12-hour window, the legacy - 6/+12-hour window, and a discharge-inclusive phenotype were sensitivity audits.

Sparse definitions were not over-modelled. Analyses with fewer than 100 exposed patients or no more than five exposed deaths were descriptive; otherwise, only the prespecified M1 adjustment was permitted. This rule applied to the symptom-plus-ECG, high-specificity ECG, and strict-clock ECG definitions.

Definition-component observability and database portability

For each Fifth-UDMI component, we recorded the relevant denominator, EHR support, operationally observable count, and residual interpretation gap. Components included serial troponin change above an available URL, a sex-specific URL, symptoms, early ECG evidence, time-locked imaging, coronary thrombus, MI mechanism, and procedure-related MI. Fitness for purpose was assessed by asking whether the expected source and format were represented, whether the element was present in the relevant denominator and time window, and whether the observable field was an adequate clinical proxy. Without human-adjudicated reference data, this was verification of observable fields rather than clinical validation [23, 24]. Procedure-related assessment requires a combination of procedure timing, acute myocardial injury, clinical or ECG features, and—depending on the scenario—angiographic, anatomical, and cardiac imaging evidence [1]. These inputs were not jointly available. Machine reports were treated as proxies rather than expert ECG interpretations, and ED chief complaints as partial histories rather than complete symptom assessments.

Portability was assessed against four operational requirements: equivalent source modality, comparable time anchor, sufficient assay/unit/URL metadata, and linkable records at the person-encounter level. The eICU audit included each adult's first ICU stay with at least two same-test-unit troponin values from 6 hours before to 24 hours after admission and a $\geq 20\%$ relative change. eICU lacks equivalent ECG text, ED chief-complaint text, approved URL maps, and systematic time-locked imaging; it could not reconstruct or externally evaluate the MIMIC information construct. We therefore limited eICU analyses to structured-data availability, assay-unit distributions, and an assay-specific absolute-delta audit using the upper quartile within each assay-unit cell.

Outcome, covariates, and statistical analysis

The outcome was index-facility mortality and was analysed as secondary clinical context for the observability audit. M0 contained the information construct alone. The main M1 model in all 6189 encounters added a centred natural cubic spline for age with 4 degrees of freedom (boundary knots 18 and 100 years; internal knots 38.25, 58.50, and 78.75 years), recorded sex, and calendar period. In the 5412-encounter multimodal-selected cohort, M2 additionally included peak troponin/available-URL ratio, relative change, number of measurements, and serial duration; M3 added ED acuity, triage vital signs, and early laboratory measurements using median imputation with missingness indicators. Because several M3 variables may follow the information construct and may be consequences, mediators, or colliders, all estimates were interpreted as non-causal.

Logistic models produced whole-cohort standardised risks, risk differences, and risk ratios with HC3 covariance. Confidence intervals used delta-method gradients of counterfactual mean risks. The prespecified ECG analysis fitted positive, negative, and unavailable status in all 6189 encounters, with negative as reference, and directly compared positive with negative status among the 4911 encounters with a strict-window report. Recorded-sex and calendar-period interactions were exploratory. M1 variables were complete after explicit unknown-category handling; no imputation was required for the main contextual model. M3 retained missingness indicators and did not use complete-case exclusion.

The study used the census of eligible records, so no a priori sample-size calculation was performed. Mortality models were descriptive rather than hypothesis-confirming. No multiplicity correction was applied to exploratory interactions or sensitivity analyses; exact estimates and confidence intervals were emphasised, and P values were not interpreted as binary evidence.

Selection bias was addressed by using all 6189 eligible encounters as the primary cohort. We compared the 5412-encounter multimodal subset with the full cohort, cross-tabulated source combination by ECG status, and repeated the captured-union M1 model among patients with an available strict-window report. Inverse-probability-of-selection weights used age, recorded sex, year group, peak troponin/URL ratio, number of measurements, and serial duration; weights were stabilised and truncated at the 1st and 99th percentiles. The selection model, truncation, weighted outcome model, and standardisation were repeated in 500 patient bootstraps.

The supplementary stress-burden analysis evaluated seven triage or first-valid laboratory proxies from -1 to < + 6 hours in patients with at least six observable domains. Four fixed logistic models distinguished a core set, core plus the burden summary, core plus raw components, and core plus raw components plus the summary. Five repeated five-fold validations fitted preprocessing and modelling within each training fold. The incremental summary effect beyond raw components was evaluated with 200 patient bootstraps that refitted the complete workflow; duplicate resampled encounters were grouped by their stable analysis identifier and could not cross folds. Analyses used PostgreSQL 18 and Python 3.12.14 with seed 20260924.

Use of generative artificial intelligence

OpenAI Codex (OpenAI; accessed 24 and 29 September 2026) assisted with code drafting and statistical analysis. It was not used for clinical adjudication, and no direct identifiers or patient-level records were included in the submission materials provided to the tool. The authors reviewed the code, analyses, citations, figures, interpretation, and final text and retain full responsibility for the work.

Results

Cohort and source decomposition

The earliest qualifying selected-troponin encounter was retained for 23553 adults. Of these person-index encounters, 15409 met the pragmatic dynamic rule and 8144 did not. After the combined ED-source and common-module-era restrictions, 6189 of the 15409 dynamic encounters formed the primary cohort and 9220 did not enter it (Fig. 1); available aggregate outputs do not separate those two restriction reasons. Of the primary cohort, 5412 met the multimodal rule used for sensitivity analyses. The primary cohort included 680 deaths (10.99%). Captured symptom-or-machine-ECG evidence was present in 1479 patients: symptom only in 1271, ECG only in 138, and both in 70; 4710 had neither captured source (Table 2). Within this reference group, 3595 had an available machine-ECG report without a prespecified positive phrase and 1115 had no linked report in the strict window (Additional file 1: Table S1b).

Table 1
Operational observability of Fifth-UDMI components

Component	Required information	EHR support	Operationally observable n/N (%)	Residual interpretation gap
Acute myocardial injury	Rise and/or fall in cTn with ≥ 1 value above the assay- and sex-specific 99th-percentile URL	Partially supported	6189/6189 (100.0%)	Pragmatic rule used a locally recorded non-sex-specific URL and relative-change thresholds; this did not establish Fifth-UDMI acute myocardial injury
Assay threshold	Sex-specific 99th-percentile URL	Unavailable	0/6189 (0.0%)	Only locally recorded non-sex-specific URLs were available
Ischaemia—symptoms	Ischaemic symptoms at presentation	Partially supported	6189/6189 (100.0%)	ED chief complaint was available but was not a complete clinician history
Ischaemia—ECG	New ischaemic ECG changes in the strict early window	Partially supported	4911/6189 (79.4%)	Machine reports were proxies; no expert over-read or prior-ECG comparison was available
Ischaemia—imaging	New regional wall-motion abnormality or loss of viable myocardium	Unavailable	0/6189 (0.0%)	No systematic time-locked imaging result was extractable
Ischaemia—coronary thrombus	Angiographic or autopsy evidence	Not operationalised	0/6189 (0.0%)	No validated time-locked structured variable was available
MI mechanism	Primary versus secondary MI classification	Not adjudicable	0/6189 (0.0%)	Stress-domain proxies could not establish causal mechanism
Procedure-related MI	Procedure timing, acute myocardial injury, clinical/ECG features, and required coronary or cardiac imaging	Not adjudicable	0/6189 (0.0%)	The required procedure, anatomical, ECG, and imaging inputs were not jointly available
Operationally observable means that a source field or proxy required for the audit was present. It does not mean that the corresponding Fifth-UDMI clinical component was fully evaluable or fulfilled; 100% denotes proxy-field presence only. cTn, cardiac troponin; ECG, electrocardiogram; ED, emergency department; EHR, electronic health record; MI, myocardial infarction; UDMI, Universal Definition of Myocardial Infarction; URL, upper reference limit.				

Table 2
Cohort characteristics by captured evidence

Characteristic	Neither captured source (n = 4710)	Captured evidence (n = 1479)	SMD
Age, years	74 (63–84)	67 (56–78)	0.353
Female sex	2187 (46.4%)	532 (36.0%)	0.214
Selected troponin measurements, n	3 (2–3)	3 (2–3)	0.227
Serial span, h	13.60 (8.50–17.67)	14.67 (10.02–18.55)	0.188
Peak troponin/available URL	10 (4–34)	34 (7–126)	0.348
Index-facility mortality	621 (13.18%)	59 (3.99%)	—
Evidence source	No captured symptom or positive ECG phrase: 4710	Symptom only 1271; ECG only 138; both 70	—
Values are median (interquartile range) or n (%). Captured evidence was an ischaemic ED chief complaint or a prespecified positive machine-ECG phrase from – 1 to < + 2 hours. Neither captured source means that neither signal was captured; it includes 1115 patients without a linked machine-report ECG in the strict window and does not mean a clinically negative ECG. The union is heterogeneous and symptom dominated. ECG, electrocardiogram; SMD, standardised mean difference; URL, upper reference limit.			

Among 6254 candidate ECGs in the strict window, 272 positive reports occurred in 208 patients. Positive-report timing was a median 16 minutes after arrival (interquartile range 8–44). Of the 208 positive patients, 205 had at least one report containing ‘consider acute infarct’; four had a broad match on a report without that phrase, with one patient contributing both report types.

Definition-component observability

The pragmatic serial-troponin rule was cohort defining but only approximated Fifth-UDMI acute myocardial injury, and sex-specific URLs were unavailable. Chief-complaint text was present for all 6189 eligible encounters but was only a partial proxy for an ischaemic-symptom history. A linked ECG report occurred in the strict window for 4911 (79.4%). Systematic time-locked imaging, coronary-thrombus evidence, mechanism adjudication, and the procedure-related MI requirements were not supported by the extracted fields (Table 1; Additional file 1: Table S9).

ECG visibility and secondary mortality context

Strict-window ECG status was positive in 208 patients (29 deaths), negative in 4703 (493 deaths), and unavailable in 1278 (158 deaths). In the all-eligible three-state M1 model, standardised risks were 14.72%, 10.54%, and 12.01%, respectively (omnibus $P = 0.079$). Positive versus negative status gave a risk difference of + 4.18 percentage points (95% confidence interval [CI] -0.80 to + 9.16) and a risk ratio of 1.397 (95% CI 0.991–1.968); unavailable versus negative status gave + 1.46 percentage points (95% CI -0.61 to + 3.54) and 1.139 (95% CI 0.954–1.360). Among 4911 ECG-available encounters, the direct

positive-versus-negative risk difference was + 4.25 percentage points (95% CI -0.72 to + 9.23), with a risk ratio of 1.407 (95% CI 0.998–1.983) (Table 3). These adjusted descriptive associations were imprecise and do not imply a causal effect.

Table 3
Secondary mortality models by ECG status and captured evidence

Analysis	Exposed/reference	Standardised risk: exposed/reference	Risk difference, pp (95% CI)	Risk ratio (95% CI)
All eligible: ECG positive vs negative, M1	208/4703	14.72%/10.54%	+ 4.18 (-0.80 to + 9.16)	1.397 (0.991–1.968)
All eligible: ECG unavailable vs negative, M1	1278/4703	12.01%/10.54%	+ 1.46 (-0.61 to + 3.54)	1.139 (0.954–1.360)
ECG available: positive vs negative, M1	208/4703	14.71%/10.46%	+ 4.25 (-0.72 to + 9.23)	1.407 (0.998–1.983)
All eligible: captured union vs neither, M1	1479/4710	4.04%/13.14%	-9.11 (-10.53 to -7.68)	0.307 (0.235–0.401)
ECG available: captured union vs neither, M1	1316/3595	4.24%/12.93%	-8.69 (-10.28 to -7.10)	0.328 (0.248–0.433)
Multimodal-selected: selection-weighted union, M1	1341/4071	4.05%/12.86%	-8.81 (-10.31 to -7.34)*	0.315 (0.237–0.417)
The ECG-status model used negative as reference; its two-degree-of-freedom omnibus P value was 0.079. Unavailable means no linked machine-report ECG in the strict window and does not establish that no ECG was acquired or interpreted. Mortality associations are secondary descriptive context and are not causal effects, diagnostic effects, or measures of care quality. *Selection interval from 500 patient bootstraps repeating selection-model fitting, weight truncation, outcome-model fitting, and standardisation. CI, confidence interval; ECG, electrocardiogram; pp, percentage points.				

Observed mortality was 3.99% (59/1479) with captured symptom-or-machine-ECG evidence and 13.18% (621/4710) with neither captured source. The all-eligible captured-union M1 risk difference was – 9.11 percentage points (95% CI -10.53 to -7.68); symptom evidence alone gave – 10.74 (95% CI -12.04 to -9.45). The opposite direction of the ECG-specific contrast demonstrates that the union is a symptom-dominated documentation pathway rather than a coherent biological phenotype. In the multimodal-selected cohort, the union M1 risk difference was – 8.65; adding troponin features gave – 10.04, whereas the post-index M3 estimate was – 2.72 (95% CI -4.65 to -0.79).

Sensitivity, prediction, and portability analyses

The symptom-plus-early-ECG stratum contained 70 patients and four deaths. Excluding 'consider acute infarct' left four high-specificity ECG-positive patients and two deaths; the strict-clock definition contained ten patients and one death. These analyses remained descriptive under the sparse-data rule. The recorded-sex interaction P value was 0.846. Calendar-period estimates varied, with an interaction P value of 0.033 and standardised risk differences ranging from – 6.07 to -11.39 percentage points; these exploratory strata were not interpreted as causal effect modification.

Of the 1278 patients with unavailable ECG status, 1115 were in the neither-captured-source group and 163 had symptom evidence. Restricting the captured-union model to ECG-available encounters was consistent with the full-cohort union estimate, whereas the direct ECG-positive-versus-negative model addressed a separate question. Selection weights ranged from 0.897 to 1.659 after truncation and yielded an effective sample size of 5246. In the multimodal-selected cohort, the selection-weighted risk difference was – 8.81 percentage points; the full-process 500-bootstrap interval was – 10.31 to -7.34. Measured balance improved, but structural missingness and unmeasured selection remain possible.

The exploratory early-window subset contained 834 patients and 72 deaths. Repeated leakage-free validation gave an area under the receiver operating characteristic curve (AUC) of 0.797 and calibration slope of 0.748 for the core-plus-raw-components model. Adding the burden summary yielded an AUC of 0.802 and slope of 0.739: change in AUC + 0.005 (200-replicate refitted-validation interval – 0.009 to + 0.031) and change in Brier score + 0.00055 (-0.00133 to + 0.00253). The summary showed no robust incremental value, and calibration remained overfitted.

The eICU portability audit contained 19581 stays across 188 hospitals. Troponin I and troponin T were both recorded as ng/mL but had different absolute-delta distributions; assay-specific upper-quartile thresholds were 3.121 and 0.550 ng/mL. eICU supplied no equivalent early ischaemic-evidence construct and was not used for external validation or the main outcome comparison.

Discussion

Principal findings

This historical EHR audit found that routinely captured fields could not reconstruct all Fifth-UDMI components in 6189 eligible encounters. The observation concerns retrospective data fitness for purpose, not implementation of a definition published after the care period. Sex-specific URLs, systematic time-locked imaging, thrombus evidence, mechanism classification, and procedure-related adjudication were unavailable. The symptom-or-machine-ECG union was driven by symptom wording and a tentative machine phrase; it should be understood as a documentation-pathway marker rather than a diagnosis or biological phenotype.

Time anchoring and source decomposition changed the interpretation. Within the – 1 to < + 2-hour window, 1271 patients were symptom only, 138 ECG only, and 70 had both signals. The neither-captured-source group also contained two distinct data states: 3595 patients had an available non-positive

machine report, whereas 1115 had no linked report in the window. In the direct ECG analysis, adjusted mortality was numerically higher for positive than negative status, but both the full-cohort and ECG-available confidence intervals crossed the null. Conversely, symptom evidence was associated with lower mortality. These opposing source-specific patterns preclude a protective interpretation of the combined construct.

Informatics interpretation

The Fifth UDMI functioned usefully as a structured requirements checklist. The audit separated four questions that are often conflated in computable phenotyping: whether a component is conceptually required, whether an EHR module could represent it, whether a record was linked in the relevant time window, and whether the observed field is clinically adequate. This source-time mapping extends established fitness-for-purpose frameworks by making the intended clinical decision time and residual interpretation gap explicit [23, 24]. A machine interpretation is not an expert over-read; a chief complaint is not a complete history; a local non-sex-specific URL is not the required assay- and sex-specific threshold. Preserving these distinctions makes absence states explicit and limits semantic overreach.

This component-to-source mapping is transferable even when the particular MIMIC field definitions are not. The generalisable contribution is the audit method rather than the MIMIC-specific phrase set or a new MI phenotype: other sites can map a clinical definition to local sources, time anchors, linkage rules, and semantic gaps before developing decision support. A site considering an audit or decision-support workflow should document source coverage, timestamp semantics, identifier linkage, assay metadata, report vocabulary, prior-result availability, and the route by which imaging or procedural evidence becomes observable. The eICU comparison illustrates why portability cannot be inferred from shared variable names: different modality coverage and assay distributions prevented reconstruction of an equivalent early-evidence construct.

Imaging can reclassify provisional diagnoses and identify occult coronary or structural disease [14], while international consensus supports pragmatic cardiovascular review despite uncertainty in secondary MI criteria [15]. These clinical observations reinforce the informatics conclusion: an EHR flag can identify a record requiring review only after the underlying data pathways have been verified locally against source records. It cannot supply missing clinical adjudication.

Implications for evaluation and implementation

Any translation should begin as a governed audit rather than a bedside classifier. The denominator becomes identifiable only after serial troponin qualification, which may require observations through 24 hours. A + 2-hour visibility flag and a 48-hour review target are illustrative parameters, not validated standards. A silent prospective phase with human source review should quantify module coverage, linkage error, phrase precision, alert yield, reviewer workload, time to appropriate evaluation, unnecessary antithrombotic or invasive testing, delayed treatment of non-coronary illness, and disparities by age, sex, race or ethnicity, language, and arrival mode.

The exploratory prediction analysis does not justify deployment. The burden summary added only 0.005 AUC beyond the raw physiologic components, its refitted-validation interval crossed zero, and it did not improve the Brier score. Calibration slopes below one indicated overfitting. This result is consistent with heterogeneous troponin-risk associations in sepsis and other acute illnesses [16, 17] and argues against repackaging familiar physiologic abnormalities as a new score. Future models should focus on a defined use case, mechanism-relevant inputs [18–20], external evaluation, and current prediction-reporting and risk-of-bias guidance [21, 22].

Strengths and limitations

Strengths include the use of all 6189 eligible encounters as the primary cohort, an explicit information-time boundary, direct source and machine-phrased decomposition, a definition-component observability matrix, three-state ECG representation, transparent selection analyses, and repeated validation in which duplicate bootstrap encounters could not cross folds. The supplied aggregate artifacts and code provide an auditable link between reported estimates and analysis outputs.

The limitations are substantial. No human-reviewed reference standard was available, so correctness and clinical adequacy could not be validated. Chief-complaint text is an incomplete history, and machine ECG text is not expert interpretation. The pragmatic troponin thresholds and early information window were operational choices, and alternate thresholds were not evaluated. Assay- and sex-specific URLs, systematic time-locked imaging, thrombus evidence, and procedure-related adjudication were unavailable. Index-facility mortality is short term. The captured-evidence union combines clinically different sources; selection weighting addresses measured variables only; and M2, especially M3, includes variables that may follow the information construct. The 834-patient prediction subset was selected by data availability and remained internally evaluated. MIMIC represents one historical health system, and temporal or contemporary-site validity was not established; eICU lacked the modalities needed for equivalent reconstruction or external validation.

Conclusions

Historical routine EHR data only partially supported retrospective assessment of Fifth-UDMI components. Source provenance, timing, linkage, and explicit unavailable states materially affected interpretation. Captured symptom-or-machine-ECG evidence was a heterogeneous, wording-dependent pathway marker; its mortality association was secondary descriptive context and did not establish diagnosis, missed disease, care quality, or treatment effects. The defensible next step is local prospective source verification with human review before any clinical alert or diagnostic model is considered.

Abbreviations

AUC
area under the receiver operating characteristic curve

CI
confidence interval
ED
emergency department
ECG
electrocardiogram
EHR
electronic health record
MI
myocardial infarction
MIMIC
Medical Information Mart for Intensive Care
pp
percentage points
RECORD
Reporting of studies Conducted using Observational Routinely-collected health Data
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
UDMI
Universal Definition of Myocardial Infarction
URL
upper reference limit.

Declarations

Ethics approval and consent to participate

The MIMIC-IV database was approved by the Institutional Review Boards of Beth Israel Deaconess Medical Center (protocol 2001-P-001699/14) and the Massachusetts Institute of Technology (0403000206), with a waiver of informed consent because the data are retrospective and deidentified. eICU-CRD was released under its original ethical approvals and meets Health Insurance Portability and Accountability Act Safe Harbor standards. This secondary analysis used deidentified, publicly available data under PhysioNet data-use agreements; no additional ethical approval or consent was required. All procedures were conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article and its additional files. Patient-level MIMIC-IV, MIMIC-IV-ED, MIMIC-IV-Note, MIMIC-IV-ECG, and eICU-CRD source data are available to credentialed users through PhysioNet, subject to its access requirements and data-use agreements, and cannot be redistributed by the authors. Aggregate source data supporting the submitted tables and figures are provided in Additional file 2, and the PostgreSQL and Python extraction and analysis code, manifests, expected invariants, and verification instructions are provided in Additional file 3. Neither archive contains patient-level records or original hospital identifiers.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HWT contributed to conceptualization and methodology. ZL performed the formal analysis. ZC developed the software. ZXL contributed to visualization and writing the original draft. YCX provided clinical interpretation. YMN verified the analytical outputs and contributed to writing—review and editing. FXY provided supervision, resources, and project administration. All authors read and approved the final manuscript and agree to be accountable for the work.

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Authors' information

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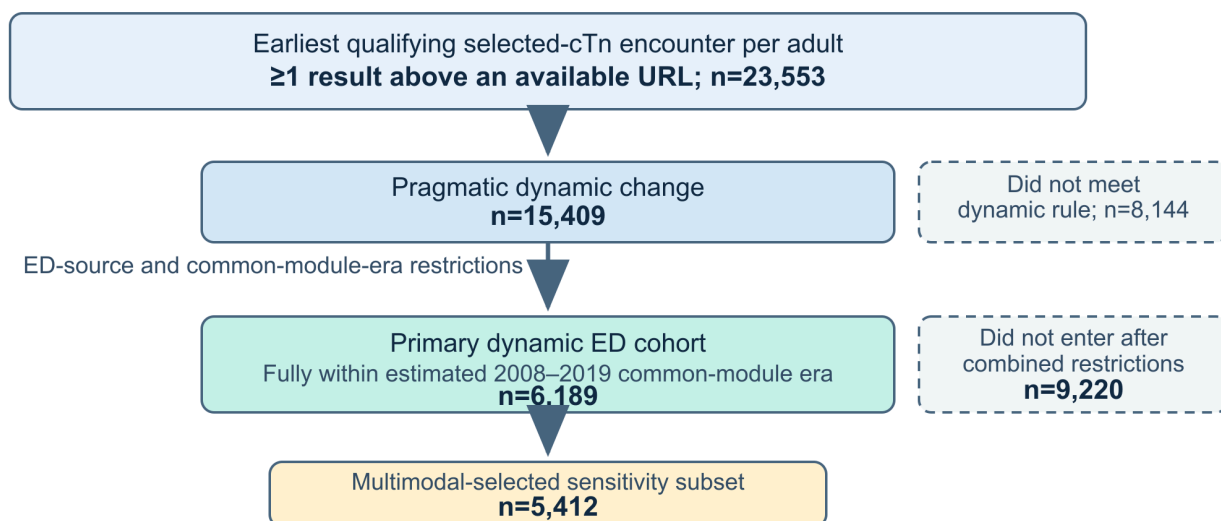
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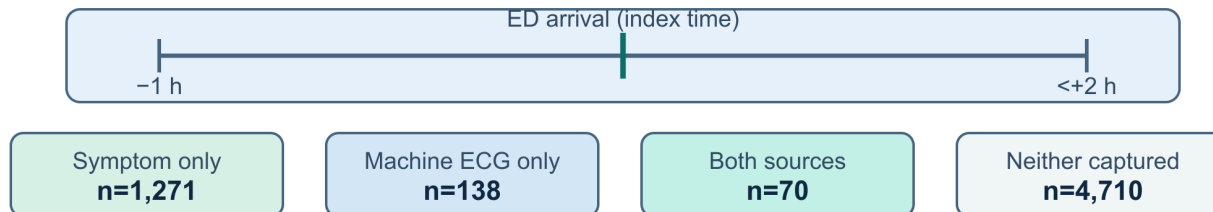
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Figures

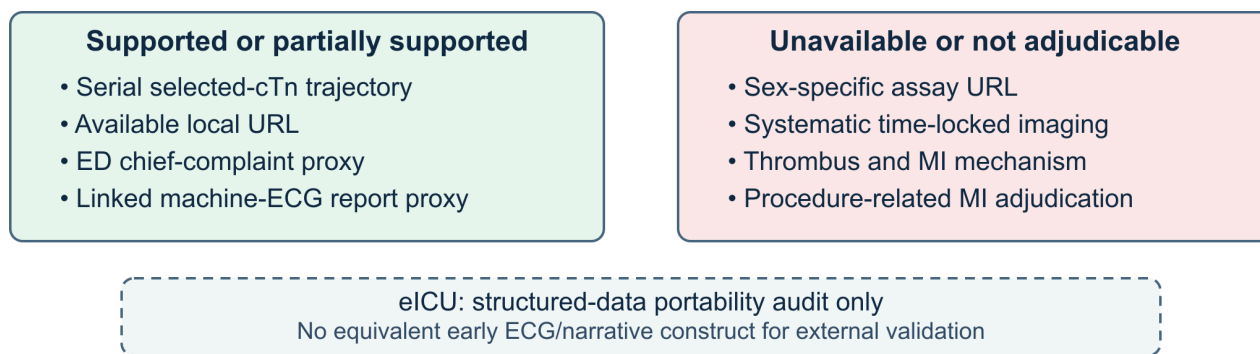
a MIMIC-IV cohort assembly



b Strict information window and captured sources



c Fifth-UDMI operational-observability boundary



cTn, cardiac troponin; ECG, electrocardiogram; ED, emergency department; MI, myocardial infarction; URL, upper reference limit

Figure 1

Cohort assembly, information window, and database roles. Panel A shows the earliest selected-troponin encounter for 23553 adults, of whom 15409 met the pragmatic dynamic-troponin rule and 8144 did not. After the combined ED-source and common-module-era restrictions, 6189 encounters formed the primary cohort and 9220 did not enter it; available aggregate outputs do not separate those restriction reasons. Of the primary cohort, 5412 entered the multimodal-selected subset used only for sensitivity analyses requiring additional variables. Panel B shows the -1 to $<+2$ -hour window and four symptom/ECG source combinations. Panel C shows the Fifth-UDMI operational-observability boundary. eICU lacked equivalent ECG, narrative, URL, imaging, and procedure-adjudication information and served

only as a structured-data portability audit. cTn, cardiac troponin; ECG, electrocardiogram; ED, emergency department; URL, upper reference limit.

Alt text: Flow diagram showing MIMIC cohort assembly, the strict ECG window, four symptom/ECG source combinations, and a boundary between partially supported and unavailable Fifth-UDMI components; eICU is labelled as a portability audit.

Supplementary Files

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- [Additionalfile1SupplementaryMaterial.docx](#)
- [Additionalfile2SourceData.zip](#)
- [Additionalfile3ReproducibilityCode.zip](#)