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ORIGINAL RESEARCH

Cardiac Comorbidity Risk Score: Zero-Burden Machine Learning to Improve Prediction of Postoperative Major Adverse Cardiac Events in Hip and Knee Arthroplasty

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BACKGROUND: In this retrospective, observational study we introduce the Cardiac Comorbidity Risk Score, predicting perioperative major adverse cardiac events (MACE) after elective hip and knee arthroplasty. MACE is a rare but important driver of mortality, and existing tools, eg, the Revised Cardiac Risk Index demonstrate only modest accuracy. We demonstrate an artificial intelligence-based approach to identify patients at high risk of MACE within 4 weeks (primary outcome) of arthroplasty, that imposes zero additional burden of cost/resources.

METHODS AND RESULTS: Cardiac Comorbidity Risk Score calculation uses novel machine learning to estimate MACE risk from patient electronic health records, without requiring blood work or access to any demographic data beyond that of sex and age, and accounts for variable/missing/incomplete information across patient records. Validated on a deidentified cohort (age >45 years, n=445 391), performance was evaluated using the area under the receiver operator characteristics curve (AUROC), sensitivity/specificity, positive predictive value, and positive/negative likelihood ratios. In our cohort (age 63.5±10.5 years, 58.2% women, 34.2%/65.8% hip/knee procedures), 0.19% (882) experienced the primary outcome. Cardiac Comorbidity Risk Score achieved area under the receiver operator characteristics curve=80.0±0.4% (95% CI) for women and 80.1±0.5% (95% CI) for males, with 36.4% and 35.1% sensitivities, respectively, at 95% specificity, significantly outperforming Revised Cardiac Risk Index across all studied age-, sex-, risk-, and comorbidity-based subgroups.

CONCLUSIONS: Cardiac Comorbidity Risk Score, a novel artificial intelligence-based screening tool using known and unknown comorbidity patterns, outperforms state-of-the-art in predicting MACE within 4 weeks postarthroplasty, and can identify patients at high risk that do not demonstrate traditional risk factors.

Key Words: hip and knee arthroplasty ■ machine learning ■ Revised Cardiac Risk Index ■ risk of MACE

Major adverse cardiac events (MACE), consisting of myocardial infarction and cardiac arrest, are rare early complications in patients undergoing total hip or total knee arthroplasty.[1–11] Total hip and knee arthroplasty are frequently performed surgeries in older adults with multiple cardiac comorbidities, and yet the overall frequency of MACE is low, complicating identification of high-risk patients. Risk calculators used to predict postoperative MACE following lower extremity arthroplasty have shown modest accuracy.[10,12] The Revised Cardiac Risk Index (RCRI)[13] is a widely used preoperative risk calculator that uses existing cardiovascular (CVD) comorbidities and surgical procedural risk to determine perioperative risk for MACE. RCRI does not include many other known CVD risk factors or identify patients without a formal diagnosis

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CLINICAL PERSPECTIVE

What Is New?

- The Cardiac Comorbidity Risk Score (CCoR) is introduced to predict perioperative major adverse cardiac events 2–4 weeks after elective hip and knee arthroplasty.
- CCoR is based on known and yet unknown comorbidity signatures extracted via sophisticated processing of individual patient history of medical encounters without any new laboratory tests or blood work, making it applicable at the point of care, and easily integrable with existing electronic healthcare management systems.

What Are the Clinical Implications?

- CCoR outperformed the Revised Cardiac Risk Index to identify patients at high-risk of perioperative major adverse cardiac events in patients undergoing hip and knee arthroplasty.
- The CCoR performed well for patients with no Revised Cardiac Risk Index conditions as it effectively identified patients at high-risk of major adverse cardiac events with no previously diagnosed Revised Cardiac Risk Index conditions.
- Integration of the CCoR into electronic healthcare management systems can improve preoperative risk stratification and reduce healthcare costs as compared with the Revised Cardiac Risk Index over the next 2 decades.

Nonstandard Abbreviations and Acronyms

CCoR	Cardiac Comorbidity Risk Score
MACE	major adverse cardiac events
PFSA	Probabilistic Finite State Automata
RCRI	Revised Cardiac Risk Index

of CVD comorbidities, which may limit its ability to predict perioperative MACE. In this study we sought to develop and validate a more accurate screening tool by systematically incorporating a vastly wider array of comorbidity patterns, including ones that are not already known risk factors for perioperative MACE.

To put in context, machine learning algorithms have been recently applied to assess risk of serious postoperative complications in procedures ranging from liver, pancreatic, colorectal surgeries, gastrectomies, and general in-patient procedures.[14–18] However, use of such tools for lower extremity arthroplasty has not been reported. Additionally, most reported approaches use manually curated fixed set of input features involving results of specific laboratory tests, patient demographic information to populate the inputs to the machine learning tools. This requirement imposes additional burden on patients, and caregivers, and can exacerbate healthcare use. We aimed to develop a "zero-burden" tool, that may be applied without any such specific data demands, and be operable with the existing patient history on file.

To accomplish this goal, we built upon our previous work[19–22] on algorithmic pattern discovery in electronic health records databases. As a part of a broader trend of applying machine learning in medicine,[23,24] these algorithms identify complex characteristics of comorbidity incidence, timing, sequence, and synchronism, that presage various diagnoses and outcomes,[19] in this case, MACE in the 4 weeks after total hip arthroplasty and total knee arthroplasty. Combining these discovered features with standard machine learning leads to an automated screening tool based only on diagnostic codes already existing in the patient's medical record. Risk screening using such algorithms therefore entails no additional diagnostic testing or other interventions for the patient, and no completion of risk calculators or other inputs by health professionals. In this study we develop and validate our screening tool for MACE after total hip arthroplasty/total knee arthroplasty, referred to as the Cardiac Comorbidity Risk Score (CCoR). We hypothesized that CCoR would show strong predictive ability on a standalone basis and outperform the RCRI in identifying patients at high risk of myocardial infarction and cardiac arrest following lower extremity arthroplasty.

METHODS

Data and Software Availability

Restrictions apply to some or all the availability of data analyzed during this study because they were used under license. The corresponding author will on request detail the restrictions and any conditions under which access to some data may be provided. A working version of the software tool developed in this study, free for non-commercial evaluation, will be made available by the corresponding author on request. To enable fast execution, some compute intensive features are disabled in this version. Results from this software are for demonstration purposes only, and must not be interpreted as medical advice, or serve as replacement for such.

Data Source, Patient Selection, and Ethics

Our patient data derive from the Truven Health Analytics MarketScan Commercial Claims and Encounters Database[25] for the years 2003–2018 (the "Truven data set"). The Truven data set combined deidentified patient records from >150 insurance carriers and large self-insurance companies including Medicare Advantage and provides comprehensive inpatient and outpatient healthcare data obtained for >87 million patients. The Truven data set contains *International Classification of Diseases, Ninth* and *Tenth Revisions* (*ICD-9* and *ICD-10*) diagnosis codes, current procedural terminology codes, as well as patients' age at arthroplasty and sex. Our study sample from the Truven data set based on the inclusion and exclusion criteria noted in Table S1 and Figure S1 (CONSORT-artificial intelligence extension diagram). In particular, we included patients with a current procedural terminology code that indicated either a total hip arthroplasty or total knee arthroplasty (Table S2). After the initial cohort selection, we applied the following exclusion criteria to patients: (1) <45 years of age, (2) active enrollment in the insurance plan for <12 months before surgery, and (3) continued enrollment in the insurance plan for <26 weeks following surgery. The University of Chicago Institutional Review Board granted an exemption for informed consent since this is an observational study using deidentified data (ID: IRB21-1272).

We use the RCRI version published in 1999,[13] which is calculated on a scale from 0 to 6 points, with 1 point assigned for each of the following conditions: history of (1) ischemic heart disease, (2) heart failure, and (3) cerebrovascular disease, (4) insulin therapy for diabetes, and (5) serum creatinine >2.0 mg/dL; 1 to 3 are identified by the presence of any of the diagnosis codes listed in Table S3 in inpatient or outpatient claims data, and insulin therapy was identified based on at least 1 outpatient prescription for insulin in the year before arthroplasty. Since the Truven database contained insufficient laboratory data on preoperative serum creatinine, we used an *ICD* diagnosis code for chronic kidney disease stage III or higher as a surrogate for creatinine >2.0 mg/dL.[11,26]

The sixth condition contributing to the RCRI is high-risk surgery which includes intraperitoneal surgery, suprainguinal vascular surgery and thoracic surgery. Since our cohort is limited to total hip and knee arthroplasty patients, the maximum number of conditions possible in the context of this study is 5 as enumerated in Table 1 (the contribution from the sixth category is always 0). We map the RCRI score to risk of MACE using published values,[27] and use this estimated risk value for evaluating RCRI performance when comparing with CCoR.

Outcome

The primary outcome was a MACE diagnosis, defined as myocardial infarction or cardiac arrest, within the 4 weeks of the date of the elective primary total arthroplasty of the hip or knee. MACE events were included if any of the *ICD* codes shown in Table S4 were

Table 1. Patient Characteristics

Characteristic, n (%)	All surgeries (N=445 391)	MACE within 2 wk (n=722)	MACE within 4 wk (n=882)	No MACE* (n=444 509)
Mean age at surgery (SD)	63.5 (10.5)	70.8 (10.3)	70.8 (10.3)	63.4 (10.5)
Men	185 992 (41.8%)	385 (53.4%)	464 (52.7%)	185 528 (41.8%)
Women	259 399 (58.2%)	337 (46.6%)	418 (47.3%)	258 981 (58.2%)
Knee surgery	293 153 (65.8%)	451 (62.4%)	559 (63.4%)	292 594 (65.8%);
Hip surgery	152 238 (34.2%)	271 (37.6%)	323 (36.6%)	151 915 (34.2%)
RCRI score				
0	295 960 (66.6%)	213 (29.5%)	265 (30.0%)	295 695 (66.6%)
1	101 505 (22.7%)	238 (32.9%)	300 (34.0%)	101 205 (22.7%)
2	37 145 (8.3%)	186 (25.9%)	212 (24.1%)	36 933 (8.3%)
3	9336 (2.1%)	70 (9.6%)	88 (9.9%)	9247 (2.1%)
4	1438 (0.3%)	15 (2.1%)	16 (1.8%)	1422 (0.3%)
5	7 (0.002%)	0 (0%)	0 (0%)	7 (0.002%)
Chronic kidney disease: stage III or higher†	18 774 (4.2%)	97 (13.4%)	111 (12.5%)	18 663 (4.1%)
Ischemic heart disease	98 840 (22.1%)	413 (57.2%)	497 (56.3%)	98 343 (22.1%)
Congestive heart failure	26 309 (5.9%)	139 (19.2%)	167 (18.9%)	26 142 (5.8%)
Cerebrovascular disease	64 642 (14.5%)	230 (31.8%)	279 (31.6%)	64 363 (14.4%)
Preoperative treatment with insulin	783 (0.17%)	1 (0.13%)	1 (0.11%)	782 (0.17%)

MACE indicates major adverse cardiac events; and RCRI, Revised Cardiac Risk Index.

*The "NO MACE" cohort comprised patients with no recorded MACE in their records during the 26 weeks after arthroplasty.

†Because of insufficient availability of relevant laboratory data in the Truven data set, presence of at least 1 diagnostic code for chronic kidney disease stage III or higher in the medical record in the year before the date of arthroplasty was used as a surrogate for the Revised Cardiac Risk Index condition, serum creatinine concentration >2.0 mg/dL.

documented in the medical record during the 4 weeks after arthroplasty. If a patient experienced multiple events during the 4 weeks postarthroplasty, we considered the first one. The 4-week time frame was chosen to be consistent with previous analyses evaluating the timing, incidence, and prediction of MACE after major noncardiac surgery.[4] As a secondary outcome, we evaluated MACE prediction within 2 weeks of surgery.

Modeling and Prediction

To predict postsurgical MACE we aimed to classify time-stamped sequences of diagnostic codes into positive and control categories, where the positive category refers to patients experiencing the primary outcome. The control cohort comprised patients without any MACE in their records within the 26 weeks after the surgery. For both groups, we based our predictions on the 52 weeks of medical history before the total joint arthroplasty. We considered altogether >126 million diagnostic codes (>36 000 unique codes) (Table S5) in a sex-stratified analysis. We did not preselect any diagnostic code based on its association with MACE risk, using pattern discovery to find predictive precursors instead.

We proceeded by partitioning the set of all diagnostic codes into 26 broad categories (Tables S6 and S7; Figure 1), referred to as "CCoR phenotypes". Some of the phenotypes encompass a relatively large number of codes aligning roughly with *ICD* categories.[17,18,25,28] Other phenotypes include ≥1 codes that might have some known or suspected association with MACE. One such phenotype is "frailty" (Table S7), recognized to increase risk of such adverse cardiac outcomes.[29,30] Applied to the individual timestamped history of diagnoses, each phenotype yields a single time series over weeks. Here each week is assigned a value "0" if no code recorded in that week corresponds to the phenotype, "1" if some code in that phenotype is present, or "2" if a diagnostic code from any other phenotype is present. Ultimately each patient is represented by 26 sparse stochastic event streams, which are compressed into specialized Hidden Markov Models known as Probabilistic Finite State Automata (PFSA).[20,21] These models are inferred separately for each phenotype, for each sex, and for the control and the positive cohorts, ie, 26×2×2=104 PFSA models are inferred altogether, to identify the distinctive average comorbidity patterns emerging at the population level. Variation in the structure and parameters of these inferred models between the positive and control groups delineated the estimated population-level risk of postoperative MACE. Given these models, and a specific patient's history, we can quantify the log-likelihood (Table S8) of that history being generated by the control PFSA models as opposed to the positive models. We refer to this difference in likelihood as the sequence likelihood defect[22] (see Data S1) which is one of the key informative features in our approach. Besides the phenotype-specific Markov models, we used a wide range of engineered features that reflect various aspects of the patient-specific diagnostic histories (Table S8). Overall, we computed a total of 380 features for each patient, which were then used to train a standard gradient boosting classifier[31,32] aiming to map individual patients to a raw risk score. Importantly, these features are derived solely from the information available in the patient electronic health records file, with no additional blood work or tests. It is important to note that the trinary encoding described above leads to ≈87% to 89% 0's, 1% 1's, and ≈9% to 11% 2's (Table S9). Since the 1's code for a specific category of disorders, while 2's for all remaining categories, it is expected that 2's will be more frequent.

All performance metrics are evaluated on held-back out-of-sample data, ie, on the validation set. We randomly chose 50% of our patients for training the algorithm, with the rest makes up the validation set. Half of the training data set was used for PFSA inference, and the rest for training the gradient boosting classifier. In addition to gradient boosting classifier, we experimented with other prominent classification models including random forests and extremely randomized trees.[33] The gradient boosting classifier emerged as the optimal choice with the highest out-of-sample performance given the initial feature engineering steps discussed above.

Chart Completeness

Records of medical encounters for patients cannot be guaranteed to be over identical time periods, especially when using a large claims database. Thus, we designed our approach to be applicable to patients with varying lengths of medical histories. The underlying models do not need equal-length inputs for computation. Importantly, we use only data within the inference period. If the set of recorded encounters for a patient do not span at least the past 12 months (52 weeks), then that patient is excluded, as described in our inclusion/exclusion criteria. Prospective studies in the future will evaluate applicability in such short-history situations.

Imbalance Between Positive and Control Cohorts

The incidence of MACE in patients undergoing total hip/knee replacement is low (0.3%–0.9%),[1] and ≈0.2% in our data set. Such severe imbalances can skew predictors. However, this is not an important issue in our analysis since all reported performance are obtained on out-of-sample data. Nevertheless, we investigated if using a more balanced data set for training would boost

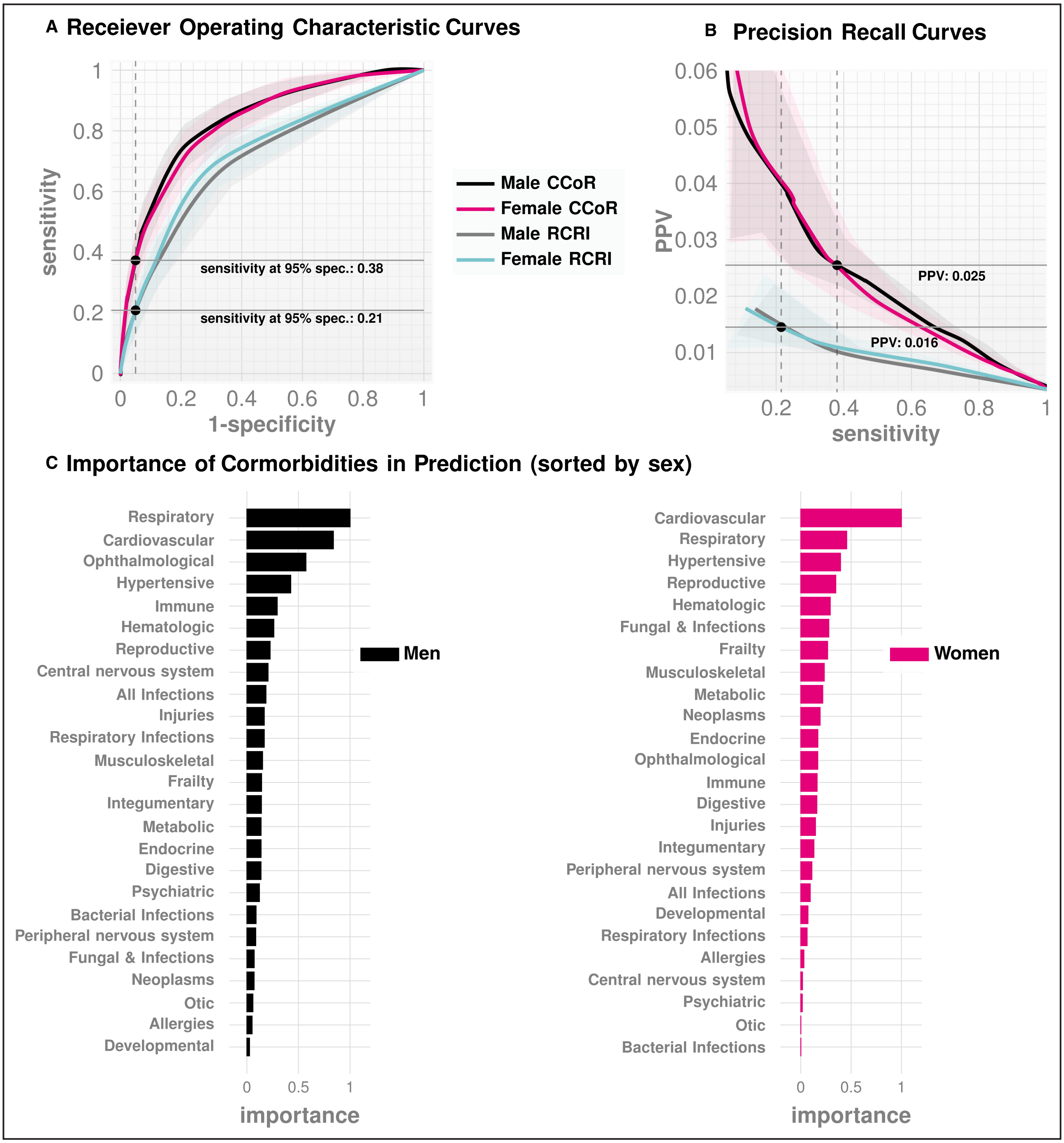

Figure 1. Out-of-sample performance of Cardiac Comorbidity Risk Score (CCoR) and Revised Cardiac Risk Index (N=445391) to predict major adverse cardiac events in the 4 weeks after elective primary lower extremity arthroplasty.
The validation cohort comprised the 50% of the study sample not used to develop CcoR. **A** and **B**, The receiver operating characteristics and precision-recall curves, respectively, of the two risk scores by sex. The AUROC of the receiver operating characteristics curve and the precision-recall curve reflect the risk scores' performance in predicting major adverse cardiac events 4 weeks after elective primary total hip or knee joint replacement. CcoR shows a strong prognostic performance that substantially exceeds that of Revised Cardiac Risk Index in both men and women. **C**, The relative importance of phenotypes (comorbidity phenotypes) in CcoR estimation. The 20 top phenotypes by sex are shown in descending order of relative importance in estimating the CcoR. Notably, these importances do not merely sum the predictive contribution from the presence or absence of individual diagnostic codes, a contribution reflected in the comorbidity spectra illustrated in Figure 2. Rather, the relative importance of the phenotypes sums the predictive contribution from all *patterns* (sequence likelihood defect as well as sequence features, see Methods) emerging from all disorders comprising each phenotype. Note that the sex of the patient matters, eg, respiratory disorders are somewhat overrepresented in women and circulatory disorders in men, and only 3 of the top 5 and 5 of the top 10 phenotypes are shared between women and men. CcoR indicates Cardiac Comorbidity Risk Score; RCRI, Revised Cardiac Risk Index; ROC, receiver operating characteristics; and SLD, Sequence Likelihood Defect.

Figure 2. Comorbidity spectra.

Disorders that increase the odds of a "true positive" vs a "true negative"; ie, these disorders, ranked here according to the log-odds ratio in ascending order of frequency in "true posititive" versus "true negative" patients, are more likely in patients who are in the positive cohort. *ICD-10* indicates *International Classification of Diseases, Tenth Revision*. Panel A and B shows comorbidity spectra for the two sexes, which while similar, have important differences.

our out-of-sample performance. We verify explicitly (Table S10) that such as a strategy confers no advantage, and in fact leads to progressive degradation of performance in out-of-sample data as we use more balanced data for training (a matched one-is-to-one balanced data set yields an out-of-sample AUROC of 75.5% for the female cohort, as opposed to >80% when no balancing is attempted). We suspect that any down-sampling to balance the training data causes the predictor to only focus on a subset of patterns, which then makes it less capable of assessing risk in out-of-sample data.

Feature Importance and Comorbidity Spectra

In addition to estimating risk, our analysis offers insights into the known and unknown comorbid associations of postoperative MACE, via the inferred relative importance of the features used. We computed the relative importance of the features by estimating the mean change in the raw risk via random perturbations of the features (Figure 1C). Additionally, we computed the statistically significant log-odds ratios of specific *ICD* codes occurring in the true positive versus the true negative patient sets, defining the "comorbidity spectra" (Figure 2). Importantly, the comorbidity spectra are based on individual codes, as opposed to the feature importance shown in Figure 1, which consider the aggregated impact of all features. Every disorder listed in the comorbidity spectra obviously does not appear in a given patient's records, but codes with high log-odds ratio are significantly more likely in the positive cohort.

Statistical Analysis

When executed just before surgery, our models predict the raw risk score for a MACE within 4 (or 2) weeks of the procedure. Given the raw estimate, a decision threshold is chosen to make a balanced trade-off between Type 1 and Type 2 errors (or, equivalently, between specificity and sensitivity): if the raw risk is greater than this calibrated threshold, then the patient is predicted to be in the positive category, ie, likely to experience MACE. We compared the out-of-sample predictive performance for CCoR and RCRI using standard metrics, including accuracy, the area under the receiver operating characteristic curve (AUROC), sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios (LR+ and LR−, respectively). The 95% CIs on ROC curves and AUROCs were obtained via bootstrapping, and AUROC *P* values were obtained using the Mann–Whitney *U*-test statistic.[34]

Cost Analysis

The low prevalence of MACE implies that statistically significant predictive advantage alone might not make a sufficiently convincing case for the clinical relevance of the performance superiority of CCoR over RCRI. Thus, we evaluated the relative impact of the algorithms in a simple cost model, which also accounts for the impact of relatively high false positive rate arising because of the low prevalence of MACE.

Recent publication of the AJRR (American Joint Replacement Registry) puts the number of total hip/knee replacement procedures at 1.7M (2020),[35] and is projected to be 1.9M in 2025, 2.8M in 2030, and 4.8M in 2040.[36] Mean MACE-related costs incurred for the first event occurring within a few weeks of surgery is high, and was recently estimated to be \$19 642.[37] The reported 30-day incidence (after total hip/knee arthroplasty) of MACE varies from 0.3% to 0.9%.[1] The additional procedures, testing and increased length of hospital stay because of a positive flag from a chosen risk assessment algorithm is estimated to be ≈\$10 624 per patient.[38] These estimates inform our cost model designed to compare the clinical value added by CCoR versus RCRI. In particular, we estimate the cost (C) per year to the healthcare system as a result of MACE, with perioperative risk assessment performed by any given algorithm to be:

$$C = (t_p + f_p)C_t + f_n C_M$$

where t_p, f_p, f_n are true positives, false positives, and false negatives, and C_t, C_M are the costs per patient for additional testing, and those incurred after experiencing MACE respectively, thus explicitly accounting for the impact of false positives and false negatives. The above equation reduces to:

$$C = \left(s\left(\frac{C_t}{PPV} - C_M\right) + C_M\right)\rho N$$

where s is the sensitivity of the chosen algorithm, ρ is the prevalence of MACE among patients undergoing the surgical procedure, and N is the estimated number of procedures performed per year.

RESULTS

Our cohort (Table S11) included 445 391 patients undergoing lower extremity arthroplasty, with 0.19% experiencing the primary outcome of MACE within 4 weeks of the procedure (including 0.16% within 2 weeks of surgery). Patient characteristics overall and in the positive and control (negative) cohorts can be seen in Table 1. Rates of MACE within 4 weeks of surgery were 0.21% in patients undergoing total hip arthroplasty and 0.19% in those undergoing total knee arthroplasty, respectively. Table S11 presents the subcohort sizes stratified by sex and the presence or absence of MACE within 4 weeks of arthroplasty.

CCoR Performance

The key performance metrics for CCoR to predict the primary outcome are presented in Table 2 and Figure 1, which illustrates the ROC curve, the AUROC, and the precision-recall curves, respectively, shown separately for women and men along with 95% CI. Performance for predicting MACE within 2 weeks of surgery is enumerated in Table 3. For predicting MACE 4 weeks postarthroplasty, out-of-sample AUROC was 80.1±1.9% (95% CI) for women and 80.2±1.8% (95% CI) for men, with 36.4±6% and 35.1±1% sensitivities, respectively, at 95% specificity. CCoR accuracy (the fraction of correct predictions) of 95%, and a PPV (the fraction of true positives among all positive flags) of 2.5% was achieved irrespective of sex. It should be noted that because of the low prevalence of MACE in our sample, even 100% sensitivity for a screening tool at 95% specificity would yield a PPV <5%. Given the low prevalence, the likelihood ratios are more relevant metrics here. For the primary outcome of MACE within 4 weeks of surgery, for women, CCoR achieved a LR+ of 7.28±0.3 at 95% specificity (13.19±2.1 at 99% specificity), implying that the odds of a positive CCoR flag in female patients who do experience MACE is 7.28 times to that in patients who do not, when the tool is operated at 95% specificity. For men, the corresponding LR+ are 7.19±2 and 12.44±0.3 at 95% and 99% specificity, respectively. Similarly, we achieved LR− of 0.67±0.05 for women and 0.68±0.01 for men at 95% specificity, implying that the odds of a negative CCoR result in a patient not experiencing MACE is 1/0.67=1.5 times more than that in patients who do. For the secondary outcome of MACE within 2 weeks of surgery, CCoR achieves an LR+ of 7.5±2.5 (women) and 7.65±0.6 (males) at 95% specificity, and 14.48±0.3 (women) and 13.98±2.1 (men) at 99% specificity. The corresponding LR− estimates for the 2-week horizon are 0.87±0.01 (99% specificity) and 0.66±0.03 (95% specificity) for both sexes. These results show that CCoR is particularly effective when there is a positive flag (high LR+), and moderately so for negative flags.

CCoR performance in predicting the primary outcome in all studied age-, risk-, and comorbidity-defined subgroups of the validation cohort was comparable with the overall out-of-sample performance (Table 2, Tables S12 and S13). The score's performance remained high, albeit slightly decreased, when predictions of 4-week MACE with 99% specificities were considered (Table S14). CCoR performance was slightly stronger (AUROC 80.9±2.1% in women, 81.3±1.9% in men) for the shorter time horizon of 2 weeks postoperatively (Table 3 and Table S15).

Performance Comparison With RCRI

Tables 2 and 3 also display performance metrics at 95% specificity for the RRCI to predict the primary and secondary outcomes. In both sexes, (Figure 3) and across all studied age-, risk-, and comorbidity-defined subgroups (Tables S12 and S13), the AUROC for CCoR exceeded that of RRCI, often substantially. This pattern held true when specificity was set to 99% or for either the 2-week or the 4-week time frame (Tables S14 and S15). The differences in positive likelihood ratios are dramatic: CCoR LR+ is ≈62% to 78% larger, and LR− is 24% smaller at 95% specificity for the primary outcome. At 99% specificity, the positive and negative likelihood ratios are 110% to 163% larger and 1% to 6% smaller, respectively. At the shorter horizon of 2 weeks, the ratios are similar to that of the primary outcome.

Importantly the CCoR achieved high performance (76.5±0.7% in women, 76.6±1.1% in men, 95% CI) in patients lacking any RCRI condition (RCRI score of 0) for the 4-week prediction horizon, who represented nearly two thirds of the study sample (n=296 539, 66.5%) and accounted for 29.5% of all patients who suffered a cardiac event (ie, 29.5% of events occurred in RCRI=0 patients). The dramatic positive likelihood ratio in this subcohort (9.4±3.8 and 7.25±1.3 for at 95% specificity, 21.8±1.3 and 5.96±0.9 at 99% specificity for men and women, respectively, see Table 2 and Table S14), demonstrates utility to accurately risk-stratify patients completely missed by current screening tools. Also of interest, CCoR performance significantly exceeds that reported by Harris et al[10] to predict 30-day cardiac complications of elective lower extremity total joint arthroplasty. Harris and colleagues achieved an AUROC of 72%–73%±2%, 95% CI, using a limited number of preselected binary comorbidity indicators and patient demographics.

The substantial superiority in achieved out-of-sample AUROC of CCoR over RCRI were found to be statistically significant across different subcohorts that we investigated (Table S16), for both the primary and secondary outcomes.

Cost Comparison Between CCoR and RCRI

With the values of the parameters chosen as described in our cost model (and using a prevalence of 0.3% for MACE), we estimate that the overall cost varies with the chosen sensitivity and the PPV as shown in Figure 3A and 3B, respectively. Under current practice, a common operating point to trigger referral for preoperative tests and corrective measures, is an estimated RCRI risk >6%.[27] We estimated that this maps approximately to a sensitivity between 30% and 40% for MACE within 4 weeks of surgery. The

Table 2. Out-of-Sample* Prediction of MACE With 4 Weeks of Hip/Knee Arthroplasty (Primary End Point) at 95% Specificity: CCoR Versus RCRI†

Sex	Cohort	Model	Sensitivity	PPV	Accuracy	LR+	LR−	AUROC
Women	<65	RCRI	0.10±0.01	0.008±0.000	0.947±0.006	0.47±0.0	0.93±0.00	0.639±0.039
Women	<65	CCoR	0.31±0.01	0.025±0.010	0.948±0.006	7.31±3.1	0.72±0.01	0.775±0.035
Men	<65	RCRI	0.18±0.02	0.015±0.007	0.947±0.000	4.23±2.3	0.87±0.02	0.682±0.034
Men	<65	CCoR	0.34±0.00	0.030±0.014	0.948±0.006	8.97±4.7	0.69±0.01	0.783±0.030
Women	65+	RCRI	0.16±0.02	0.012±0.002	0.947±0.000	3.35±0.5	0.88±0.02	0.664±0.028
Women	65+	CCoR	0.32±0.01	0.022±0.010	0.948±0.006	6.48±3.0	0.71±0.01	0.771±0.025
Men	65+	RCRI	0.16±0.03	0.011±0.001	0.947±0.006	3.17±0.4	0.88±0.03	0.661±0.026
Men	65+	CCoR	0.27±0.00	0.019±0.006	0.948±0.006	5.57±1.8	0.77±0.00	0.762±0.023
Women	All patients	RCRI	0.18±0.02	0.014±0.002	0.947±0.000	4.13±0.6	0.86±0.02	0.688±0.023
Women	All patients	CCoR	0.36±0.06	0.025±0.001	0.948±0.006	7.28±0.3	0.67±0.05	0.801±0.019
Men	All patients	RCRI	0.20±0.02	0.017±0.002	0.947±0.000	4.83±0.5	0.84±0.02	0.705±0.020
Men	All patients	CCoR	0.35±0.01	0.025±0.006	0.948±0.006	7.19±2.0	0.68±0.01	0.802±0.018
Women	Frail‡	RCRI	0.12±0.03	0.009±0.002	0.947±0.006	2.50±0.6	0.92±0.02	0.670±0.028
Women	Frail	CCoR	0.31±0.02	0.022±0.007	0.948±0.000	6.40±2.2	0.73±0.02	0.791±0.025
Men	Frail	RCRI	0.23±0.01	0.019±0.003	0.947±0.006	5.46±0.9	0.80±0.00	0.727±0.027
Men	Frail	CCoR	0.38±0.02	0.026±0.008	0.948±0.000	7.56±2.6	0.66±0.03	0.810±0.024
Women	High risk§	RCRI	0.11±0.02	0.008±0.001	0.947±0.006	2.19±0.3	0.94±0.02	0.581±0.029
Women	High risk	CCoR	0.25±0.02	0.017±0.007	0.948±0.000	5.06±2.2	0.79±0.02	0.737±0.026
Men	high risk	RCRI	0.15±0.03	0.010±0.001	0.947±0.006	2.91±0.3	0.90±0.02	0.617±0.026
Men	High risk	CCoR	0.30±0.01	0.021±0.006	0.948±0.000	6.02±2.0	0.74±0.00	0.729±0.024
Women	Low risk‖	CCoR	0.33±0.04	0.032±0.012	0.948±0.000	9.40±3.8	0.70±0.04	0.765±0.036
Men	Low risk	CCoR	0.33±0.02	0.025±0.004	0.948±0.000	7.25±1.3	0.71±0.02	0.766±0.032

<65 indicates subcohort with patients aged ≤65 years; AUROC, area under the receiver operating characteristic curve; CCoR, Cardiac Comorbidity Risk Score; LR−, negative likelihood ratio; LR+, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value; and RCRI, Revised Cardiac Risk Index.

*50% of the study sample (n=445 391) used for validation.

†Because of insufficient availability of relevant laboratory data in the Truven data set, presence of at least 1 diagnostic code for chronic kidney disease stage III or higher in the medical record in the year before the date of arthroplasty was used as a surrogate for the Revised Cardiac Risk Index condition, serum creatinine concentration >2.0 mg/dL (to convert to micromoles per liter, multiply by 88.4).

‡*ICD* codes for frailty enumerated in Table S7.

§Low-risk status subcohort comprises patients with Revised Cardiac Risk Index score 0. For RCRI score >0, the patient is deemed to be at high risk.

‖No Revised Cardiac Risk Index performance logged for low-risk patients, since their RCRI score is zero.

estimated cost for achieving a 40% sensitivity in the general population with CCoR is ≈667M US dollars per year currently. With RCRI this estimate to 1.48B US dollars, which approximately reflects current practice (see annotation in panel B).

Additionally, at any fixed yearly cost, CCoR is estimated to deliver substantially higher sensitivity and PPV (Figure 3C and 3D), eg, if the total yearly cost to the healthcare system attributable to preoperative testing+post-MACE costs is fixed at 500M, then CCoR can deliver >150% more sensitivity, and >20% more PPV up to around the year 2025. The sensitivity advantage is estimated to be even wider at later years. If the total estimated cost is set at around current practice, then CCoR can deliver an improvement in either sensitivity or PPV >50% (Figure 3C and 3D).

DISCUSSION

Our study used novel machine learning algorithms to develop and validate a tool to identify comorbidity patterns in past diagnoses to predict postoperative MACE following total hip and knee arthroplasty. We demonstrated 2 key results: (1) our CCoR effectively predicted MACE within 2 to 4 weeks of a total hip or knee arthroplasty, and (2) CCoR is a significantly stronger predictor of perioperative cardiac morbidity after total hip and knee arthroplasty in clinical practice than RCRI. From the inferred relative importance of the features identified we conclude that respiratory and cardiovascular disorders are the most important modulators of risk,[39] followed by hematologic, reproductive, nervous system disorders and infections. While the role of past

Table 3. Out-of-Sample* Prediction of MACE With 2 Weeks of Hip\Knee Arthroplasty (Secondary End Point) at 95% Specificity: CCoR Versus RCRI†

Sex	Cohort	Model	Sensitivity	PPV	Acuracy	LR+	LR−	AUROC
Women	<65	RCRI	0.11±0.01	0.009±0.000	0.947±0.006	0.51±0.0	0.92±0.00	0.647±0.044
Women	<65	CCoR	0.32±0.07	0.025±0.005	0.948±0.006	7.30±1.6	0.71±0.06	0.787±0.039
Men	<65	RCRI	0.20±0.03	0.017±0.003	0.947±0.000	4.95±1.0	0.84±0.04	0.688±0.037
Men	<65	CCoR	0.38±0.03	0.031±0.014	0.948±0.000	9.01±4.4	0.65±0.03	0.797±0.033
Women	65+	RCRI	0.17±0.00	0.012±0.002	0.947±0.006	3.60±0.6	0.87±0.00	0.671±0.030
Women	65+	CCoR	0.31±0.02	0.022±0.012	0.948±0.000	6.37±3.8	0.72±0.02	0.787±0.027
Men	65+	RCRI	0.14±0.02	0.010±0.001	0.947±0.000	2.79±0.4	0.91±0.02	0.667±0.028
Men	65+	CCoR	0.30±0.02	0.021±0.007	0.948±0.006	6.10±2.1	0.74±0.02	0.780±0.025
Women	All patients	RCRI	0.19±0.02	0.016±0.002	0.947±0.000	4.49±0.6	0.85±0.02	0.692±0.025
Women	All patients	CCoR	0.37±0.01	0.026±0.008	0.948±0.006	7.50±2.5	0.66±0.01	0.809±0.021
Men	All patients	RCRI	0.19±0.02	0.016±0.002	0.947±0.000	4.63±0.6	0.85±0.02	0.710±0.022
Men	All patients	CCoR	0.37±0.03	0.026±0.002	0.948±0.006	7.65±0.6	0.66±0.03	0.813±0.019
Women	Frail‡	RCRI	0.14±0.02	0.011±0.002	0.947±0.000	3.13±0.7	0.90±0.03	0.676±0.032
Women	Frail	CCoR	0.31±0.03	0.023±0.003	0.948±0.000	6.75±0.8	0.73±0.04	0.807±0.027
Men	Frail	RCRI	0.23±0.03	0.019±0.003	0.947±0.000	5.40±0.8	0.80±0.03	0.736±0.029
Men	Frail	CCoR	0.41±0.04	0.028±0.002	0.948±0.000	8.20±0.7	0.62±0.04	0.825±0.025
Women	High risk§	RCRI	0.12±0.00	0.008±0.001	0.947±0.006	2.35±0.4	0.93±0.00	0.584±0.032
Women	High risk	CCoR	0.23±0.05	0.017±0.003	0.947±0.006	4.90±0.8	0.81±0.04	0.742±0.028
Men	High risk	RCRI	0.13±0.01	0.009±0.001	0.947±0.006	2.69±0.4	0.91±0.00	0.628±0.028
Men	High risk	CCoR	0.33±0.03	0.023±0.002	0.948±0.000	6.57±0.6	0.71±0.03	0.737±0.026
Women	Low risk‖	CCoR	0.43±0.03	0.041±0.017	0.948±0.006	12.20±5.7	0.60±0.03	0.779±0.040
Men	Low risk	CCoR	0.39±0.02	0.029±0.005	0.948±0.000	8.57±1.5	0.64±0.02	0.793±0.035

<65 indicates subcohort with patients aged ≤65 years; AUROC, area under the receiver operating characteristic curve; CCoR, Cardiac Comorbidity Risk Score; LR+, positive likelihood ratio; LR−, negative likelihood ratio; NPV, negative predictive value; PPV, positive predictive value; and RCRI, Revised Cardiac Risk Index.

*50% of the study sample (n=445 391) used for validation.

†Because of insufficient availability of relevant laboratory data in the Truven data set, presence of at least 1 diagnostic code for chronic kidney disease stage III or higher in the medical record in the year before the date of arthroplasty was used as a surrogate for the Revised Cardiac Risk Index condition, serum creatinine concentration >2.0 mg/dL (to convert to micromoles per liter, multiply by 88.4).

‡*ICD* codes for frailty enumerated in Table S7.

§Low-risk status subcohort comprises patients with Revised Cardiac Risk Index score 0. For Revised Cardiac Risk Index score >0, the patient is deemed to be at high risk.

‖No Revised Cardiac Risk Index performance logged for low-risk patients, since their Revised Cardiac Risk Index score is zero.

cardiovascular diagnoses in postoperative MACE has been recognized,[38] prior research[40–45] has examined binary relationships between the presence or absence of a diagnosis (eg, coronary artery disease). This is a major limitation for the RCRI, as a formal diagnosis of coronary artery disease or heart failure is required to identify patients at risk. Our approach can identify patients with patterns and combinations of comorbidities in past medical encounters associated with increased risk for MACE, as opposed to only those with specific CVD disorders. A key conclusion from our study is that CCoR is markedly better at predicting the occurrence of MACE, than predicting its nonoccurrence. Thus, a positive CCoR flag reliably identifies high-risk patients who may experience postoperative MACE. The reliability is lower for concluding that the absence of a CcoR flag implies no MACE in the postsurgical time frames considered. In either case, CcoR likelihood ratios are superior to RCRI.

Our approach addresses a major limitation of current comorbidity-based risk calculators that require binary diagnoses (eg, heart failure) to deduce an increased risk. Newer cardiac risk calculators, such as the American College of Surgeons National Surgical Quality Improvement Project[46] have improved upon this approach by incorporating symptoms (eg, dyspnea with moderate exertion) and functional status, but are still primarily reliant on a limited set of manually curated diagnoses. Additionally, the calculators can be challenging to incorporate into busy clinic workflows. Our approach integrates directly into standard electronic medical record systems to estimate expected cardiac risk before surgical procedures. This could be readily available to clinicians of all specialties at the

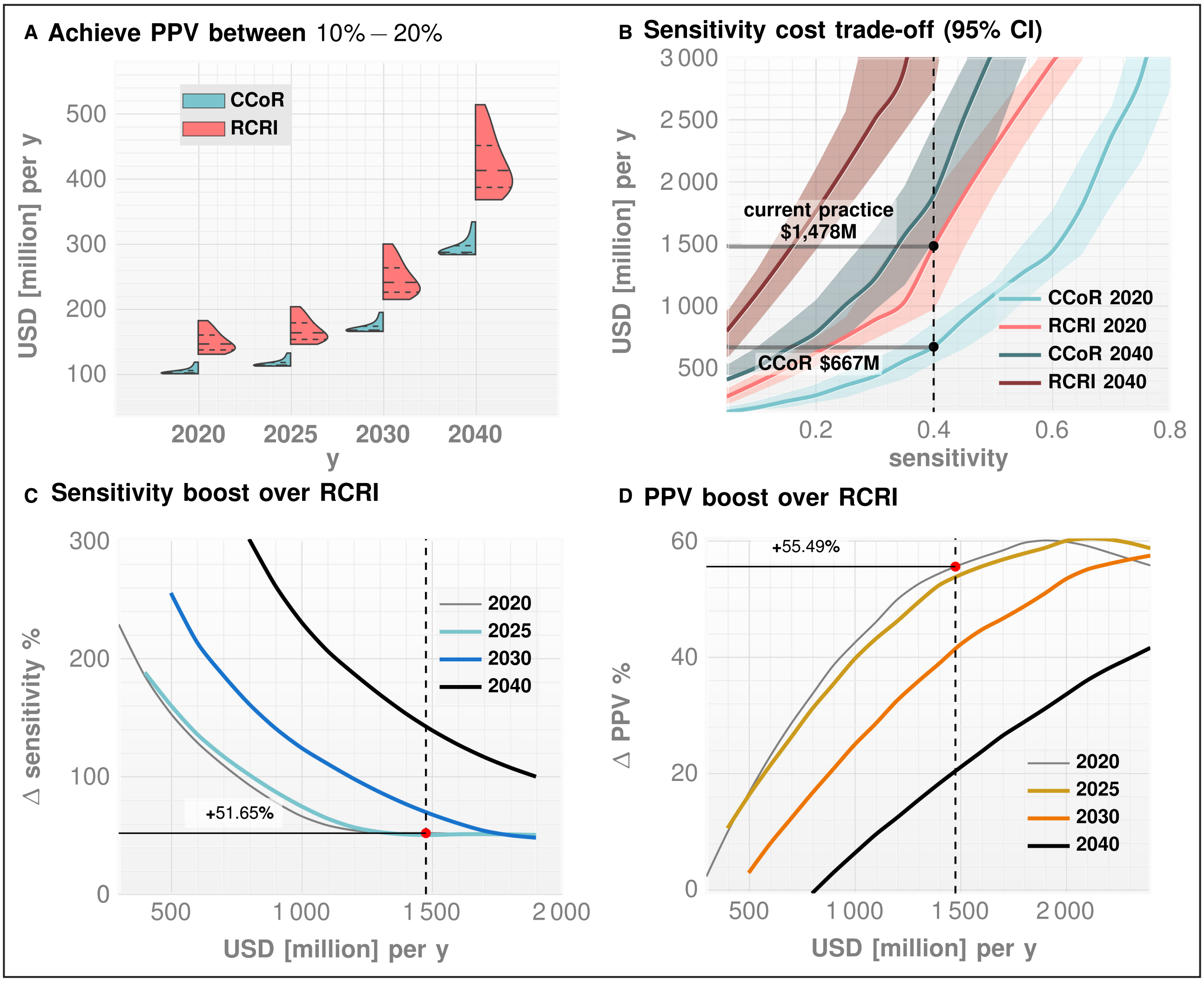

Figure 3. Cost model.

A, The distribution of estimated cost for Cardiac Comorbidity Risk Score (CcoR) and Revised Cardiac Risk Index (RCRI) over the years for achieving positive predictive value between 10% and 20%. **B**, The cost trade-off with sensitivity for 2020 and 2040 along with 95% CI. Note that the estimated cost of achieving a 40% sensitivity in the general population (which approximately corresponds to >6% risk with RCRI and reflects current practice) with CCoR is ≈750M US dollars per year currently, while with RCRI this increases to 1.5B US dollars per year. **C**, The relative boost in sensitivity achieved by CCoR over RCRI as a percentage for a fixed cost. **D**, The relative boost in positive predictive value achieved by CCoR over RCRI as a percentage for a fixed cost. Thus, if the yearly cost is fixed at 500M, then CCoR can deliver >150% more sensitivity, or almost 20% more positive predictive value up to around 2025. If the costs are set to what is estimated for current practice ($1478M), then CCoR can deliver a >50% improvement in either sensitivity or positive predictive value. The estimated number of surgeries per year, and values for the costs of additional testing on a positive flag, and for the costs incurred upon experiencing major adverse cardiac events are adopted from published estimates of comparable scenarios. CCoR indicates Cardiac Comorbidity Risk Score; PPV, positive predictive value; RCRI, Revised Cardiac Risk Index; and USD, US dollar.

time of office-based perioperative risk assessment, or even guide who should be scheduled for subspecialty risk assessment. Ultimately, patterns of healthcare use before surgical procedures can be leveraged to identify patients that may require additional testing or interventions to modify risk before a surgical procedure. Given that the Truven data set contains healthcare information from roughly 25% of the nation's population, and that our validation cohort had similar demographic characteristics to those of other published studies undergoing total joint arthroplasties,[47] CcoR performance in the present study is expected to be widely generalizable in the United States. Furthermore, the significant superiority of CcoR over RCRI across various subcohorts, and in multiple relevant metrics, points to the potential for substantial improvement in clinical outcomes on deployment.

Some observations, discussed next, related to the reported performance estimates might be of clinical interest. For RCRI, the PPV achieved for the age-related subpopulations (<65 and ≥65 years) were both lower than the PPV of the unrestricted population

Table 4. Performance Comparison of CCoR When Augmented With History of Prescribed Medications

Sex	Prediction Horizon	AUROC (CCoR)	AUROC (CCoR augmented with prescriptions data)	Sensitivity at 95% specificity (CCoR)	Sensitivity at 95% specificity (CCoR augmented with prescriptions data)
Men	2wk	81.3%	81.5%	34.1%	34.5%
	4wk	80.1%	80.5%	31.8%	32.7%
Women	2wk	80.9%	81.0%	32.5%	31.8%
	4wk	80.0%	80.3%	31.0%	30.2%

AUROC indicates area under the receiver operating characteristic curve; and CCoR, Cardiac Comorbidity Risk Score.

(Tables 2, 3 and Tables S14, S15), which is counterintuitive. However, in this study the PPVs of the different subcohorts are computed separately from that of the unrestricted cohort (indicated as "all patients" in Tables 2, 3 and Tables S14, S15). Since we compute the ROC curves independently in each subcohort, the threshold of binary decision differs from one subcohort to the next, which makes it possible for the estimated PPV to be lower in both younger and older subpopulations compared with the unrestricted cohort.

We also observe that CcoR performance is generally lower in the subcohorts (Tables 2 and 3). We suspect that the unrestricted cohort has a wider range of patient ages, each of which have a different incidence of MACE. This makes them more easily classifiable, on average, using age-at-screening as a feature when considered all together. When we define a subcohort with smaller age-variation, and compute performance within that group, then the predictive advantage of the age-variable disappears, leading to a somewhat lower predictive performance.

In this study, in addition to comorbidity signatures, we investigated how the sex and age of patients modulate MACE risk. This was motivated by the fact that sex and age are both known strong predictors of perioperative MACE.[48,49] Further, cardiovascular disease presentation, diagnosis, and management have been shown to be different between men and women.[50] In addition, patient demographics, clinical variables, specific treatments, and prescribed drugs might also be potentially important predictors, and in general, we expect the performance to improve if we add more informative features. However, it was difficult to assess this hypothesis within the constraints of our current data set which lacked patient demographic information such as race and ethnicity, or extensive data on other clinical variables. We will investigate the impact of demographic characteristics and other relevant clinical variables as part of future research. We did have access to information on the history of prescribed medications for the patients, and we explicitly investigated if adding such information improves our model. Considering the presence/absence and timing of prescriptions such as antibiotics, antidepressants, and beta-blockers did not show any significant improvement in performance (Table 4). We surmised that in the context of the problem at hand, the diagnostic history of patients already captures most of the predictive information that medication history provides, and hence the latter does not improve results.

We also investigated if the different components of our overall model are all indeed necessary. Our results show that, as expected, on their own the individual components, eg, the PFSA models, do substantially worse (Table S17).

Among the 26 studied CcoR phenotypes (Table S7), those encompassing cardiovascular and respiratory conditions unsurprisingly had high importance for predicting early postoperative MACE in both sexes (Figure 1C). Overall, the sexes differed clearly on the relative importance of phenotypes, with only 3 of the top 5 and 5 of the top 10 phenotypes the same in women and men (Figure 1C). Differences between the sexes were even more marked regarding comorbidity spectra (Figure 2). Of the 57 diagnostic codes with the highest relative prevalence in positive versus control patients, only 3 were present among both women and men, and in all cases, at a different rank: skin carcinoma of the lower limb and hip (*ICD-10* code D04.7), nonspecific malignant neoplasm of the lung in a nonspecific part of a bronchus (*ICD-10* code 34.9), and nonspecific diastolic (congestive) heart failure (*ICD-10* code I50.3).

We also estimated that CcoR has the potential to substantially reduce healthcare usage costs. While false positives increase the cost of additional confirmatory tests that must be undertaken for a positive flag, our cost model indicates that even with relatively large number of false positives (lower compared with RCRI), we are more cost-effective.

Finally, we note that a key limitation of this study is the use of administrative codes to ascertain past diagnostic history, which are vulnerable to coding errors, and do not record relevant nuances in diagnostic decisions and uncertainties. Also, while CcoR was derived using a well-validated national database of claims data, local healthcare usage patterns might require some recalibration at the level of an individual local institution. Finally, the CcoR was designed to estimate risk of early MACE following elective lower extremity total joint arthroplasty, and impact on the preoperative workup (eg, preoperative stress testing[11]) or treatment (eg, new prescriptions) will require further investigation, as will the effect, if any, on clinical and pharmacoeconomic outcomes. Thus, further research and prospective trials are necessary before CcoR can enter everyday clinical practice.

CONCLUSIONS

We developed and validated CcoR, an automated, potentially widely applicable screening tool to predict myocardial infarction and cardiac arrest in 2 to 4 weeks after primary total hip or knee arthroplasty. CcoR is solely based on patterns of comorbidity incidence, temporality, sequence, and synchronism in data already in the electronic health record, and hence spares patients diagnostic interventions and physicians the need to input and verify data for risk calculators. The impact of CcoR screening on clinical practice and on clinical and pharmacoeconomic outcomes also warrants investigation.

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Supplemental Material

Data S1
Figure S1
Tables S1–S17
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Supplemental Materials

DATA S1. SUPPLEMENTAL METHODS

A. Time-series Modeling of Diagnostic History

Individual diagnostic histories can have long-term memory [52], implying that the order, frequency, and comorbid interactions between diseases are important for assessing the future risk of our target phenotype. We analyze patient-specific diagnostic code sequences by first representing the medical history of each patient as a set of stochastic categorical time-series — one each for a specific group of related disorders — followed by the inference of stochastic models for these individual data streams. These inferred generators are from a special class of Hidden Markov Models (HMMs), referred to as Probabilistic Finite State Automata (PFSA) [53]. The inference algorithm we use is distinct from classical HMM learning, and has important advantages related to its ability to infer structure, and its sample complexity (See Supplementary text, Section VI). We infer a separate class of models for the positive and control cohorts, and then the problem reduces to determining the probability that the short diagnostic history from a new patient arises from the positive as opposed to the control category of the inferred models.

B. Inference & Event Periods

We train our predictive pipeline with all diagnostic codes that are recorded in the past 26years from the point at which a prediction is made. This period from which we use data to train our pipeline is called the "inference window". Our aim is to make predictions on the occurrence of the target diagnostic codes at 2year from the end of the inference window. For patients in the control cohort, we make sure that no target code appears for 26years after the end of the inference window. Additionally, when making predictions further into the future (upto 4 years, as described in the main text), we always make sure that the control group has no target codes for 1 year after the predcited time of diagnosis, $i.e.$, if we are making a prediction of a diagnosis 4 years in future, then control group patients are chosen to have no diagnosis in at least next 5 years.

C. Step 1: Partitioning The Human Disease Spectrum

We begin by partitioning the human disease spectrum into 26non-overlapping categories. Each category is defined by a set of diagnostic codes from the International Classification of Diseases, Ninth Revision (ICD9) (See Table SI-S7 for description of the categories used in this study). For this study, we ended up using 4879398 and 7753318 diagnostic codes for males and females respectively (17554 and 19209 unique codes) spanning both ICD9 and ICD10 protocols (using ICD10 General Equivalence Mappings (GEMS) [54] equivalents where necessary), from a total 445391 patients. Transforming the diagnostic histories to report only the broad categories reduces the number of distinct codes that the pipeline needs to handle, thus improving statistical power. Our categories largely align with the top-level ICD9 categories, with small adjustments, $e.g.$ bringing all infections under one category irrespective of the pathogen or the target organ. We do not pre-select the phenotypes; we want our algorithm to seek out the important patterns without any manual curation of the input data. For each patient, the past medical history is a sequence $(t_1, x_1), \cdots, (t_m, x_m)$, where t_i are timestamps and x_i are ICD9 codes diagnosed at time t_i. We map individual patient history to a three-alphabet categorical time series z^k corresponding to the disease category k, as follows. For each week i, we have:

$$z_i^k = \begin{cases} 0 & \text{if no diagnosis codes in week } i \\ 1 & \text{if there exists a diagnosis of category } k \text{ in week } i \\ 2 & \text{otherwise} \end{cases} \tag{1}$$

The time-series z^k is observed in the inference period. Thus, each patient is represented by 43 mapped trinary series.

D. Step 2: Model Inference & The Sequence Likelihood Defect Δ

The mapped series, disease-category, and perioperative cardiac event diagnosis-status are considered to be independent sample paths, and we want to explicitly model these systems as specialized HMMs (PFSAs). We model the positive and the control cohorts and each disease category separately, ending up with a total of 104 HMMs at the population level (26 categories, 2 perioperative cardiac event status categories: positive and control, and 2 sexes). Each of these inferred models is a PFSA; a directed graph with probability-weighted edges, and acts as an optimal generator of the stochastic process driving the sequential appearance of the three letters (as defined by Eq. (1)) corresponding to disease category, and perioperative cardiac event status-type (See Section VI in the Supplementary text for background on PFSA inference).

To reliably infer the perioperative cardiac event status-type of a new patient, $i.e$, the likelihood of a diagnostic sequence being generated by the corresponding perioperative cardiac event status-type model, we generalize the notion of Kullbeck-Leibler (KL) divergence [55] between probability distributions to a divergence $\mathcal{D}_{\mathsf{KL}}(G||H)$ between ergodic stationary categorical stochastic processes [56] G, H as:

$$\mathcal{D}_{\mathsf{KL}}(G||H) = \lim_{n\to\infty} \frac{1}{n} \sum_{x:|x|=n} p_G(x) \log \frac{p_G(x)}{p_H(x)} \tag{2}$$

where $|x|$ is the sequence length, and $p_G(x), p_H(x)$ are the probabilities of sequence x being generated by the processes G, H respectively. Defining the log-likelihood of x being generated by a process G as :

$$L(x, G) = -\frac{1}{|x|} \log p_G(x) \tag{3}$$

The cohort-type for an observed sequence x — which is actually generated by the hidden process G — can be formally inferred from observations based on the following provable relationships (See Supplementary Text Section VI, Theorem 6 and 7):

$$\lim_{|x|\to\infty} L(x, G) = \mathcal{H}(G) \tag{4a}$$

$$\lim_{|x|\to\infty} L(x, H) = \mathcal{H}(G) + \mathcal{D}_{\mathsf{KL}}(G||H) \tag{4b}$$

where $\mathcal{H}(\cdot)$ is the entropy rate of a process *[32]*. Importantly, Eq. (4) shows that the computed likelihood has an additional non-negative contribution from the divergence term when we choose the incorrect generative process. Thus, if a patient is eventually going to be diagnosed with perioperative cardiac event, then we expect that the disease-specific mapped series corresponding to her diagnostic history be modeled by the PFSA in the positive cohort. Denoting the PFSA corresponding to disease category j for positive and control cohorts as G^j_+, G^j_0 respectively, we can compute the *sequence likelihood defect* (SLD, Δ^j) as:

$$\Delta^j \triangleq L(G^j_0, x) - L(G^j_+, x) \to \mathcal{D}_{\mathsf{KL}}(G^j_0||G^j_+) \tag{5}$$

With the inferred PFSA models and the individual diagnostic history, we estimate the SLD measure on the right-hand side of Eqn. (5). The higher this likelihood defect, the higher the similarity of diagnosis history to that of women with perioperative cardiac event.

E. Step 3: Risk Estimation Pipeline With Semi-supervised & Supervised Learning Modules

The risk estimation pipeline operates on patient specific information limited to the available diagnostic history in the inference period, and produces an estimate of the relative risk of perioperative cardiac event, with an associated confidence value. To learn the parameters and associated model structures of this pipeline, we transform the patient specific data to a set of engineered features, and the feature vectors realized on the positive and control sets are used to train a gradient-boosting classifier [57]. The complete list of 380 features used is provided in Table 6.

We need two training sets: one to infer the models, and one to train the classifier with features derived from the inferred models. Thus, we do a random 3-way split of the set of unique patients into *feature-engineering* (25%), *training* (25%) and *test* (50%) sets. We use the feature-engineering set of ids first to infer our PFSA models *(unsupervised model inference in each category)*, which then allows us to train the gradient-boosting classifier using the training set and PFSA models *(classical supervised learning)*, and we finally execute out-of-sample validation on the test set. Fig. 1c in the main text shows the top 20 features ranked in order of their relative importance (relative loss in performance when dropped out of the analysis).

I. Threshold Selection on ROC Curve

Once the ROC curve has been computed, we must choose a decision threshold to trade-off true positive rate and false positive rate. In situations where the number of negatives vastly outnumber the number of positives (which is the case in our problem), it is better to base this trade-off on a measure that is independent of the number of true negatives. The two popular measures considered in the literature are accuracy and the F1-score:

$$\text{accuracy} = \frac{t_p + t_n}{t_p + f_p + f_n + t_n} \tag{6}$$

$$\text{F1} = \frac{2t_p}{2t_p + f_p + f_n} \tag{7}$$

The F1-score is the same as accuracy where the number of true negatives is the same as the number of true positives, thus partially correcting for the class imbalance.

The selection of the threshold may also be dictated by the current practice of ensuring high specificities in screening tests. Thus, a relevant clinically operating point is the one corresponding to 95% specificity, which is highlighted in Fig. 1a.

II. Note on Reciever Operating Characteristics (ROC) and Precision-recall Curves

The ROC curve is a plot between the False Positive rate (TPR) and the True Positive Rate (TPR), and the area under the ROC curve (AUC) is often used as a measure of classifier performance. For the same of completeness, we introduce the relevant definitions:

In the following P denotes the total number of positive samples (number of patients who are eventually diagnosed), and N denotes the total number of negative samples (number of patients in the control group).

Definition 1. *True positive rate, true negative rate, false positive rate, positive predictive value (**PPV**), and **prevalence** (ρ) are defined as:*

$$TPR = \frac{t_p}{P} = \frac{t_p}{t_p + f_n} \tag{8}$$

$$TNR = \frac{t_n}{N} = \frac{t_n}{t_n + f_p} \tag{9}$$

$$FPR = 1 - TNR \tag{10}$$

$$PPV = \frac{t_p}{t_p + f_p} \tag{11}$$

$$\rho = \frac{P}{N + P} \tag{12}$$

where as before t_p, t_n, f_p, f_n are true positives, true negatives, false positives, and false negatives respectively.

Note that TPR is also referred to as **recall** or **sensitivity**, and PPV is also referred to as **precision**. True negative rate is also known as **specificity**.

A **precision-recall curve**, or a PPV-sensitivity curve is a plot between PPV and TPR.

Denoting sensitivity by s, and specifciyty by c, it follows that:

$$\text{PPV} = \frac{t_p/P}{t_p/P + (f_p/N)(N/P)} = \frac{\text{TPR}}{\text{TPR} + ((N - t_n)/N)(N/P)} \tag{13}$$

$$\Rightarrow \text{PPV} = \frac{s}{s + (1 - c)(\frac{1}{\rho} - 1)} \tag{14}$$

Thus, we note that for a fixed specificity and sensitivity, the PPV depends on prevalence. Indeed, it is clear from the above argument that PPV decreases with decreasing prevalence, and vice versa.

III. Effect of Class Imbalance

ROC curves are generally assumed to be robust to class imbalance. Note that if we assume that patient outcomes are independent (which is well-justified in the case of a non-communicable condition, particularly in large databases), then t_p should scale linearly with the total number of positives P, implying:

$$\text{TPR} = \frac{t_p}{P} = \frac{t'_p}{P'} \tag{15}$$

implying that with different sizes of the set of positive samples (or negative samples), the ROC curve remains unchanged. In particular, note that even if the prevalence is very small (say 0.01%), we cannot cheat to boost the AUC by labeling all predictions as negative, or stating that risk is always zero: in that case, our P is very small, but our $t_p = 0$ strictly, implying that our TPR $= 0$, thus leading to a zero AUC. We can cheat to boost the accuracy (See the previous section), but not the AUC.

Note that while relative class sizes or imbalance does not affect the ROC (under the assumption that true positives and true negatives scale with the number of positives and negatives), very small absolute sample sizes might still result in poor performance of the model.

The precision-recall curves do get affected by class imbalance, or the prevalence, as shown by Eq (14). However, in diagnostic analysis, they are important since we are generally less interested in the number of true negatives; the ratio of false positives to the total number of positive recommendations by the algorithm is much more relevant, $i.e.$, the PPV or the precision.

IV. Generating PFSA Models From Set of Input Streams with Variable Input Lengths

Our PFSA reconstruction algorithm [53] is distinct from standard HMM learning. We do not need to pre-specify structures, or the number of states in the algorithm, and all model parameters are inferred directly from data. Additionally, we can operate either with 1) a single input stream, or 2) a set of input streams of possibly varying lengths which are assumed to be different and independent sample paths from the unknown stochastic generator we are trying to infer. At an intuitive level, we use the input data to infer the length of histories one must remember to estimate the current state, and predict futures for the process being modeled. Thus, we do not step through the symbol streams with a pre-specified model structure, and avoid the need to have equal-length inputs. More details of the algorithm are provided in the next section.

The ability to model a set of input streams of varying lengths is particularly important, since medical histories of different patients are typically of different lengths.

V. Probabilsitic Finite State Automata Inference

A. Probabilistic Finite-State Automaton

Let Σ be a finite alphabet of symbols with size $|\Sigma|$. The set of sequences of length d over Σ is denoted by Σ^d. The set of finite but unbounded sequences over Σ is denoted by $\Sigma^\star$, the Kleene star operation [58], $i.e.$ $\Sigma^\star = \bigcup_{d=0}^{\infty} \Sigma^d$. We use lower case Greek, for example σ or τ, for symbols in Σ, and lower case Latin, for example x or y, for sequences of symbols, $i.e.$ $x = \sigma_1\sigma_2 \dots \sigma_n$. We use $|x|$ to denote the length of x. The empty sequence is denoted by λ.

We denote the set of strictly infinite sequences over Σ by Σ^ω, and the set of strictly infinite sequences having x as prefix by $x\Sigma^\omega$. Let $\mathcal{S} = \{x\Sigma^\omega : x \in \Sigma^\star\} \cup \{\emptyset\}$, we can verify that $\mathcal{S}$ is a semiring [59] over Σ^ω. We use $\mathcal{F}$ to denote the sigma algebra generated by $\mathcal{S}$.

Definition 2 (Stochastic Process over Σ)**.** *A stochastic process over a finite alphabet Σ is a collection of Σ-valued random variables $\{X_t\}_{t\in\mathbb{N}}$ indexed by positive integers [56].*

We are specifically interested in processes in which the X_is are not necessarily independently distributed.

Definition 3 (Sequence-Induced Measure and Derivative)**.** *For a process $\mathscr{P}$, let $Pr_{\mathcal{P}}(x)$ or simply $Pr(x)$ denote the probability $\mathscr{P}$ producing a sample path prefixed by x. The **measure** μ_x **induced by a sequence** $x \in \Sigma^\star$ is the extension [59] to $\mathcal{F}$ of the premeasure defined on the semiring $\mathcal{S}$ given by*

$$\forall x, y \in \Sigma^\star, \mu_x\left(y\Sigma^\omega\right) \triangleq \frac{Pr\left(xy\right)}{Pr(x)}, \text{ if } Pr(x) > 0 \tag{16}$$

*For any $d \in \mathbb{N}$, the **d-th order derivative** of a sequence x, written as ϕ_x^d, is defined to be the marginal distribution of μ_x on Σ^d, with the entry indexed by y denoted by $\phi_x^d(y)$. The first-order derivative is called the **symbolic derivative** and is denoted by ϕ_x for short.*

Definition 4 (Probabilistic Nerode Equivalence and Causal States [60])**.** *For any pair of sequences $x, y \in \Sigma^\star$, x is equivalent to y, written as $x \sim y$, if and only if either $Pr(x) = Pr(y) = 0$, or $\mu_x = \mu_y$. The equivalence class of a sequence x is denoted by $[x]$ and is called a **causal state** [61]. The cardinality of the set of causal states is called the **probabilistic Nerode index**, or the Nerode index for simplicity.*

We can see from the definition that causal states captures how the history of a process influences its future. Since the probabilistic Nerode equivalence is right invariant, it gives rise naturally to a automaton structure introduced below.

Definition 5 (Probabilistic Finite-State Automaton (PFSA))**.** *A PFSA G is defined by a quadruple $(Q, \Sigma, \delta, \widetilde{\pi})$, where Q is a finite set, Σ is a finite alphabet, $\delta : Q \times \Sigma \to \Sigma$ is called the transition map, and $\widetilde{\pi} : Q \to \mathbf{P}_\Sigma$, where*

$\mathbf{P}_\Sigma$ *is the space of probability distributions over* Σ*, is called the transition probability. The entry of* $\widetilde{\pi}(q)$ *indexed by* σ *is denoted by* $\widetilde{\pi}(q, \sigma)$.

Definition 6 (Transition and Observation Matrices)**.** *The transition matrix* Π *is the* $|Q| \times |Q|$ *matrix with the entry indexed by* q, q'*, written as* $\pi_{q,q'}$*, satisfying*

$$\pi_{q,q'} \triangleq \sum_{\{\sigma \in \Sigma | \delta(q,\sigma)=q'\}} \widetilde{\pi}(q, \sigma) \tag{17}$$

and the observation matrix $\widetilde{\Pi}$ *is a* $|Q| \times |\Sigma|$ *matrix with the entry indexed by* q, σ *equaling* $\widetilde{\pi}(q, \sigma)$.

We note that both Π and $\widetilde{\Pi}$ are stochastic, *i.e.* non-negative with rows summing up to 1.

Definition 7 (Extension of δ and $\widetilde{\pi}$ to $\Sigma^\star$)**.** *For any* $x = \sigma_1 \ldots \sigma_k$, $\delta(q, x)$ *is defined recursively by*

$$\delta(q, x) \triangleq \delta\left(\delta\left(q, \sigma_1 \ldots \sigma_{k-1}\right), \sigma_k\right) \tag{18}$$

with $\delta(q, \lambda) = q$*, and* $\widetilde{\pi}(q, x)$ *is defined recursively by*

$$\widetilde{\pi}(q, x) \triangleq \prod_{i=1}^{k} \widetilde{\pi}\left(\delta\left(q, \sigma_1 \ldots \sigma_{i-1}\right), \sigma_i\right) \tag{19}$$

with $\widetilde{\pi}(q, \lambda) = 1$.

Definition 8 (Strongly Connected PFSA)**.** *We say a PFSA is strongly connected if the underlying directed graph is strongly connected [62]. More precisely, a PFSA* $G = (Q, \Sigma, \delta, \widetilde{\pi})$ *is strongly connected if for any pair of distinct states* q *and* $q' \in Q$*, there is an* $x \in \Sigma^\star$ *such that* $\delta(q, x) = q'$.

We assume all PFSA in the discussions in the sequel are strongly connected if not specified otherwise. For strongly connected PFSA G, there is a unique probability distribution over Q that satisfies $\mathbf{v}^T\Pi = \mathbf{v}^T$. This is the **stationary distribution** [63], [64] of G and is denoted as $\wp_G$, or $\wp$ if G is understood.

Definition 9 (Γ-Expression)**.** *We can encode the information contained in* δ *and* $\widetilde{\pi}$ *by a set of* $|Q| \times |Q|$ *matrices* $\boldsymbol{\Gamma} = \{\Gamma_\sigma | \sigma \in \Sigma\}$*, where*

$$\Gamma_\sigma\big|_{q,q'} \triangleq \begin{cases} \widetilde{\pi}(q, \sigma) & \textit{if } \delta(q, \sigma) = q', \\ 0 & \textit{if otherwise.} \end{cases} \tag{20}$$

Γ_σ *is called* ***event-specific transition matrix****, with the event being that* σ *is current the output.* Γ_σ *can also be extended to arbitrary* $x \in \Sigma^\star$ *by defining* $\Gamma_x = \prod_{i=1}^{k} \Gamma_{\sigma_i}$ *with* $\Gamma_\lambda = I$.

Definition 10 (Sequence-Induced Distribution on States)**.** *For a PFSA* $G = (Q, \Sigma, \delta, \widetilde{\pi})$ *and a distribution* $\wp_0$ *on* Q*, the* ***distribution on*** Q ***induced by a sequence*** x *is given by* $\wp^T_{G,\wp_0}(x) = \left[\!\left[\wp_0^T \Gamma_x\right]\!\right]$ *with* $\wp_{G,\wp_0}(\lambda) = \wp_0$*. The entry indexed by* $q \in Q$ *of the vector* $\wp_{G,\wp_0}(x)$ *is written as* $\wp_{G,\wp_0}(x, q)$*. When* $\wp_0 = \wp_G$*, the stationary distribution of* G*, we write* $\wp_{G,\wp_0}(x)$ *as* $\wp_G(x)$*, or simply as* $\wp(x)$*, if* G *is understood.*

Definition 11 (Stochastic Process Generated by a PFSA)**.** *Let* $G = (Q, \Sigma, \delta, \widetilde{\pi})$ *be a PFSA and let* $\wp_0$ *be a distribution on* Q*, the* Σ*-valued stochastic process* $\{X_t\}_{t \in \Sigma}$ *generated by* G *and* $\wp_0$ *satisfies that* X_1 *follows the distribution* $\wp_0$ *and* X_{t+1} *follows the distribution* $\wp_{G,\wp_0}(X_1 \cdots X_t)$ *for* $t \in \mathbb{N}$.

For the rest of this paper, we will assume $\wp_0 = \wp_G$ if not specified otherwise. We can show that, when initialized with $\wp_G$, the process generated by a PFSA G is stationary and ergodic. We also note the, for the process generate by G, we have $\phi_x = \wp_G(x)^T\widetilde{\Pi}$. Since $\wp_G(\lambda) = \wp_G$, the symbolic derivative of the empty sequence ϕ_λ is the stationary distribution on the symbols.

Definition 12 (Synchronizable PFSA and Synchronizing Sequence)**.** *A* ***synchronizing sequence*** *is a finite sequence that sends an arbitrary state of the PFSA to a fixed state [65]. To be more precise, let* $G = (Q, \Sigma, \delta, \widetilde{\pi})$ *be a PFSA, we say a sequence* $x \in \Sigma^\star$ *is a synchronizing sequence to a state* $q \in Q$ *if* $\delta(q', x) = q$ *for all* $q' \in Q$*. A PFSA is* ***synchronizable*** *if it has at least one synchronizing sequence. Given a sample path generated by a PFSA, we say the PFSA is* ***synchronized*** *if a synchronizing sequence transpires in the sample path.*

Definition 13 (Equivalence and Irreducibility)**.** *Two PFSA* G *and* H *are* ***equivalent*** *if they generate the same stochastic process. A PFSA* G *is said to be* ***irreducible****, if there is not another PFSA with smaller state set that is equivalent to* G.

Definition 14. *Consider a PFSA* G *over state set* Q*. For a give* $\varepsilon > 0$*, we say a sequence* x *is a* ε*-synchronizing sequence to a state* $q \in Q$ *if*

$$\|\wp_G(x) - \mathbf{e}_q\|_\infty \leqslant \varepsilon. \tag{21}$$

Algorithm 1: GenESeSS

Data: A sequence x over alphabet Σ, $0 < \varepsilon < 1$
Result: State set Q, transition map δ, and transition probability $\widetilde{\pi}$
/* Step One: Approximate ε-synchronizing sequence */
Let $L = \left\lceil \log_{|\Sigma|} 1/\varepsilon \right\rceil$;
Calculate the **derivative heap** $\mathcal{D}_\varepsilon^x$ equaling $\left\{\hat{\phi}_y^x \ : \ y \text{ is a sub-sequence of } x \text{ with } |y| \leqslant L\right\}$;
Let $\mathcal{C}$ be the convex hull of D_ε^x;
Select x_0 with $\hat{\phi}_{x_0}^x$ being a vertex of $\mathcal{C}$ and has the highest frequency in x;
/* Step Two: Identify transition structure */
Initialize $Q = \{q_0\}$;
Associate to q_0 the **sequence identifier** $x_{q_0}^{\text{id}} = x_0$ and the probability vector $d_{q_0} = \hat{\phi}_{x_0}^x$;
Let $\widetilde{Q}$ be the set of states that are just added and initialize it to be Q;
while $\widetilde{Q} \neq \emptyset$ **do**
  Let $Q_{\text{new}} = \emptyset$ be the set of new states;
  for $(q, \sigma) \in \widetilde{Q} \times \Sigma$ **do**
    Let $x = x_q^{\text{id}}$ and $d = \hat{\phi}_{x\sigma}^x$;
    if $\|d - d_{q'}\|_\infty < \varepsilon$ *for some* $q' \in Q$ **then**
      Let $\delta(q, \sigma) = q'$;
    else
      Let $Q_{\text{new}} = Q_{\text{new}} \cup \{q_{\text{new}}\}$ and $Q = Q \cup \{q_{\text{new}}\}$;
      Associate to q_{new} the sequence identifier $x_{q_{\text{new}}}^{\text{id}} = x\sigma$ and the probability vector $d_{q_{\text{new}}} = d$;
      Let $\delta(q, \sigma) = q_{\text{new}}$;
  Let $\widetilde{Q} = Q_{\text{new}}$;
Take a strongly connected subgraph of the labeled directed graph defined by Q and δ, and denote the vertex set of the subgraph again by Q;
/* Step Three: Identify transition probability */
Initialize counter $N[q, \sigma]$ for each pair $(q, \sigma) \in Q \times \Sigma$;
Choose a random starting state $q \in Q$;
for $\sigma \in x$ **do**
  Let $N[q, \sigma] = N[q, \sigma] + 1$;
  Let $q = \delta(q, \sigma)$;
Let $\widetilde{\pi}(q) = \left[\!\left[(N[q, \sigma])_{\sigma \in \Sigma} \right]\!\right]$;
return Q, δ, $\widetilde{\pi}$;

While there exists PFSA that is not synchronizable, we can show that an irreducible PFSA always has an ε-synchronizing sequence for some state q for arbitrarily small $\varepsilon > 0$. Moreover, we can show that as length increases, sequences produced by PFSA become uniformly ε-synchronizing. These two are the underpinning properties for the inference algorithm of PFSA (See Alg. 1), because they imply that ϕ_x can be used to approximate $\widetilde{\pi}(q)$ if x are properly prefixed and long enough.

Definition 15 (Joint ε-Synchronizing Sequence). *Let G and H be two PFSA over state sets Q_G and Q_H, respectively. For a fixed ε, a sequence x is said to be **jointly ε-synchronizing** to $(q, r) \in Q_G \times Q_H$ if x is ε-synchronizing to q and to r simultaneously. We define*

$$\Sigma_{\varepsilon,(q,r)}^d \triangleq \left\{x \in \Sigma^d : \ x \textit{ jointly } \varepsilon\textit{-synchronizing to } (q, r)\right\} \tag{22}$$

Definition 16 (Joint Pair of States). *Let G and H be two PFSA over state sets Q_G and Q_H, respectively. Define*

$$p_G(q, r) \triangleq \lim_{d \to \infty} p_G\left(\Sigma_{\varepsilon,(q,r)}^d\right) \tag{23}$$

*A pair of states $(q, r) \in Q_G \times Q_H$ is called a G-**joint pair** of states if $p_G(q, r) > 0$. We also define*

$$Q_c \triangleq \{(q, r) \in Q_G \times Q_H : \ (q, r) \textit{ is a } G\textit{-joint pair}\} \tag{24}$$

The inference algorithm for PFSA is called **GenESeSS** for Generator Extraction Using Self-similar Semantics. With an input sequence x and a hyperparameter ε, **GenESeSS** outputs a PFSA in the following three steps: 1) approximate an almost synchronizing sequence; 2) identify the transition structure of the PFSA; 3) calculate the transition probabilities of the PFSA. See Alg. 1 [53] for details.

Algorithm 2: Log-likelihood

Data: A PFSA $G = (\Sigma, Q, \delta, \widetilde{\pi})$ and a sequence x over alphabet Σ
Result: Log-likelihood $L(x, G)$ of G generating x

Calculate the state transition matrix Π and observation $\widetilde{\Pi}$;
Calculate the stationary distribution over states $\wp_G$ of G from Π;
Calculate the stationary distribution of alphabet $\phi_\lambda^T = \wp_G^T \widetilde{\Pi}$;
Initialize $\mathbf{p}$ by $\wp_G$ and $\mathbf{q}$ by ϕ_λ;
Let $L = 0$;
for i *from* 1 *to* $|x|$ **do**
    Let σ be the i-th entry of x;
    Let $L = L - \log \mathbf{q}|_\sigma$;
    Let $\mathbf{p}^T = [\![\mathbf{p}^T \Gamma_\sigma]\!]$ where Γ_σ is defined in 9;
    Let $\mathbf{q}^T = \mathbf{p}^T \widetilde{\Pi}$;
return $L/|x|$;

VI. Theoretical Development of Sequence Likelihood Defect

Definition 17 (Entropy Rate and KL Divergence)**.** *By entropy rate of a PFSA, we mean the entropy rate of the stochastic process generated by the PFSA [32]. Similarly, by KL divergence of two PFSA, we mean the KL divergence between the two processes generated by them [66]. More precisely, we have*

$$\mathcal{H}(G) = -\lim_{d\to\infty} \frac{1}{d} \sum_{x\in\Sigma^d} p(x) \log p(x) \tag{25}$$

and the KL divergence

$$\mathcal{D}_{KL}(G \,\|\, H) = \lim_{d\to\infty} \frac{1}{d} \sum_{x\in\Sigma^d} p_G(x) \log \frac{p_G(x)}{p_H(x)} \tag{26}$$

whenever the limits exist.

Theorem 1 (Closed-form Formula for Entropy Rate and KL Divergence)**.** *The entropy rate of a PFSA* $G = (\Sigma, Q, \delta, \widetilde{\pi})$ *is given by*

$$\mathcal{H}(G) = \sum_{q\in Q} \wp_G(q) \cdot h(\widetilde{\pi}(q)) \tag{27}$$

where $h(\mathbf{v})$ *is the based-*2 *entropy of the probability vector* $\mathbf{v}$*.*

Consider two PFSA $G = (Q_G, \Sigma, \delta_G, \widetilde{\pi}_G)$ *and* $H = (Q_H, \Sigma, \delta_H, \widetilde{\pi}_H)$ *with* μ_G *being absolutely continuous with respect to* μ_H*. Let* Q_c *be the set of* G*-joint pairs of states, we have*

$$\mathcal{D}_{KL}(G \,\|\, H) = \sum_{(q,r)\in Q_c} p_G(q, r)\, D_{KL}(\widetilde{\pi}_G(q) \,\|\, \widetilde{\pi}_H(r)) \tag{28}$$

Definition 18 (Log-likelihood)**.** *Let* $x \in \Sigma^d$*, the log-likelihood [32] of a PFSA* G *generating* x *is given by*

$$L(x, G) = -\frac{1}{d} \log p_G(x) \tag{29}$$

The calculation of log-likelihood is detailed in Alg. 2.

Theorem 2 (Convergence of log-likelihood)**.** *Let* G *and* H *be two reduced PFSA, and let* $x \in \Sigma^d$ *be a sequence generated by* G*. Then we have*

$$L(x, H) \to \mathcal{H}(G) + \mathcal{D}_{KL}(G \,\|\, H) \tag{30}$$

in probability as $d \to \infty$*.*

Proof. We first notice that

$$\sum_{x\in\Sigma^d} p_G(x) \log \frac{p_G(x)}{p_H(x)} = \sum_{x\in\Sigma^{d-1}} \sum_{\sigma\in\Sigma} p_G(x)\wp_G(x)\, \widetilde{\Pi}_G\Big|_\sigma \log \frac{p_G(x)\wp_G(x)\, \widetilde{\Pi}_G\Big|_\sigma}{p_H(x)\wp_H(x)\, \widetilde{\Pi}_H\Big|_\sigma} \tag{31}$$

$$= \sum_{x\in\Sigma^{d-1}} p_G(x) \log \frac{p_G(x)}{p_H(x)} + \underbrace{\sum_{x\in\Sigma^{d-1}} p_G(x) \sum_{\sigma\in\Sigma} \wp_G(x)\, \widetilde{\Pi}_G\Big|_\sigma \log \frac{\wp_G(x)\, \widetilde{\Pi}_G\Big|_\sigma}{\wp_H(x)\, \widetilde{\Pi}_H\Big|_\sigma}}_{D_d} \tag{32}$$

By induction, we have $\mathcal{D}_{\mathsf{KL}}(G \| H) = \lim_{d\to\infty} \frac{1}{d}\sum_{i=1}^{d} D_i$, and hence by Cesàro summation theorem [67], we have $\mathcal{D}_{\mathsf{KL}}(G \| H) = \lim_{d\to\infty} D_d$. Let $x = \sigma_1\sigma_2...\sigma_n$ be a sequence generated by G. Let $x^{[i-1]}$ is the truncation of x at the $(i-1)$-th symbols, we have

$$-\frac{1}{n}\sum_{i=1}^{n} \log \wp_H \left(x^{[i-1]}\right) \widetilde{\Pi}_H\Big|_{\sigma_i} = \underbrace{\frac{1}{n}\sum_{i=1}^{n} \log \frac{\wp_G\left(x^{[i-1]}\right)\widetilde{\Pi}_G\Big|_{\sigma_i}}{\wp_H\left(x^{[i-1]}\right)\widetilde{\Pi}_H\Big|_{\sigma_i}}}_{A_{x,n}} - \underbrace{\frac{1}{n}\sum_{i=1}^{n} \log \wp_G \left(x^{[i-1]}\right) \widetilde{\Pi}_G\Big|_{\sigma_i}}_{B_{x,n}} \tag{33}$$

Since the stochastic process G generates is ergodic, we have

$$\lim_{n\to\infty} A_{x,n} = \lim_{d\to\infty} D_d = \mathcal{D}_{\mathsf{KL}}(G \| H) \tag{34}$$

and $\lim_{n\to\infty} B_{x,n} = \mathcal{H}(G)$. □

VII. Pipeline Optimization: Hyper-training, Training, & Validation

Our pipeline comprises a network of individually trained light gradient boosting machine (LGBM) *[32]* classifiers that focus on complementary aspects of the problem, and operate on different categories of input features as described next. Importantly, some of these features need to be generated non-trivially from the raw data, and these *feature generators* have parameters that need to be trained as well (or comprise models that need to be inferred). We call this inference of the feature-generators as **hyper-training**. Importantly, this is different from the more common notion of hyper-parameters. Hyper-parameters are one or more variables whose scalar values are commonly tuned by grid-search or via some meata-heuristics to optimize classifiers, whereas hyper-training produces generators of features, not simply a set of numbers.

Hyper-training & Training

Trinary Quantization of Medical Histories: The medical histories are mapped into trinary disease-phenotype-specific data-streams to enable generation of some of the features described below, as outlined in Section -C (Step 1).

Feature Categories: The features used in the pipeline maybe categorized as follows:

PFSA scores: The PFSA scores are computed on the basis of the inferred PFSA models as described in the previous sections. The generation of the PFSA models from the trinary data-streams is the first hyper-training step. These scores consist of the negative and positive log-likelihood of a phenotype-specific quantized medical history being generated by the PFSA models for the positive cohort and the control cohort of sex-stratified patients, and the corresponding sequence likelihood defects (See SI-Section -D). Recall that PFSAs are specialized HMMs, and these measures encode the dynamics of the underlying processes, and are sensitive to the ordering, and frequency of the codes at the resolution of the disease phenotypes. Also, recall that disases pheonotypes are broad categories of diagnostic codes, and that we generate PFSA models for each category, and separately for the sexes and the positive cohort and the control cohorts).

Prevalence scores (p-scores): The p-scores focus on individual diagnostic codes, and we create a dictionary of the ratio of relative prevalence of each code (relative to the set of all codes present) in the positive category (for each sex) to the control category. This is the second hyper-training step. In the later steps of the pipeline, we use dictionary look ups to map codes to their p-scores, and also their aggregate measures such as mean, median, and variance to train a downstream LGBM.

Rare scores: These scores consist of a subset of p-scores which correspond to codes with particularly high and low relative prevalences (p-score > 2 or $< .5$). Thus, this feature category depends on the p-score dictionary generated in the second hyper-training step.

Sequence scores: Sequence scores are relatively straight-forward statsitical measures such as mean, median, variance, time since last occurrence $etc.$. on the trinary phenotype-specific sex-stratified histories. No hyper-training is required for the generation of the sequence features.

Thus we require three splits of the training dataset. The first split is used to carry out hyper-training of the PFSA models and the p-score dictionary. The second split is used to train the score-category specific LGBMs, one for each feature category. And the third split is used to train the final LGBM that takes inputs from the outputs of the four LGBMs in the previous layer.

Validation

In validation, or actual prediction of patient fate, we use the trinary mapping, generate the features using the PFSA models and the p-score dictionary, and calculate the raw-risk via the trained LGBM network. The relative score is then obtained by a choice of the operating point reflecting the specificity/sensitivity trade-off discussed before.

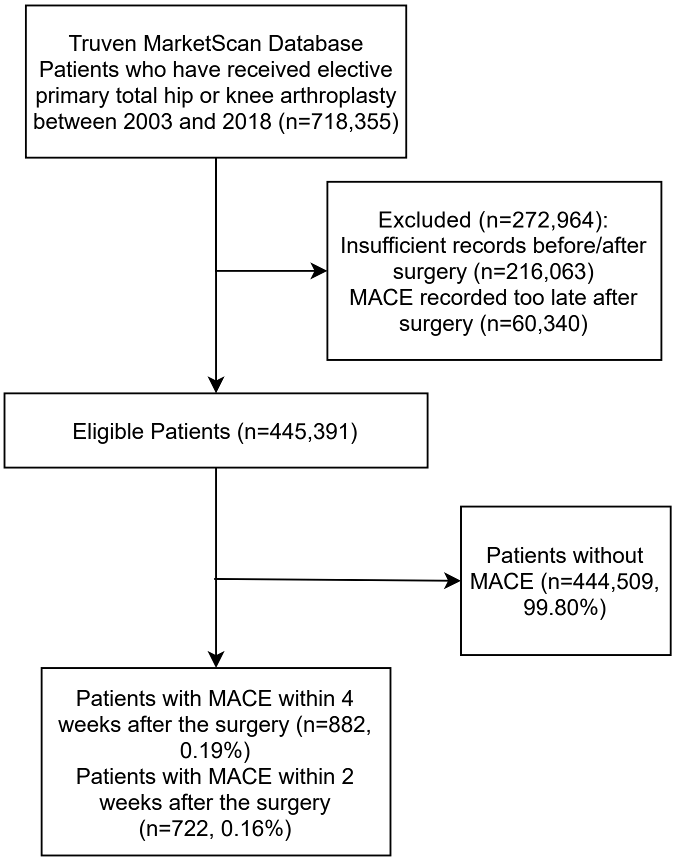

Figure S1: CONSORT diagram conforming to the CONSORT-AI Extension guidelines stated at https://doi.org/10.1016/S2589-7500(20)30218-1

Table S1: Inclusion/Exclusion, Positive/Control Criteria & Cohort Definitions

	Definitions
Inclusion/Exclusion Criteria	Age 45 - 95
	Has total hip/knee CPT codes (See Table S2) in medical history and length of history available before cardiac event spans $\geqslant$ 1 year
	Has a myocardial infarction or a cardiac arrest[‡] (See Table S4 for list of target codes used to identify cardiac event in diagnostic history) 4 weeks (2 weeks considered in secondary analysis) after surgery (positive cohort)
	Has 0.5 yr of medical history available after surgery (control)
Positive & Control Cohorts	**Positive Cohort:** At least one code for cardiac event (Table S4)
	Control Cohort: No code on cardiac event within 26 weeks of surgery

Table S2: Current Procedural Terminology (CPT) codes for total hip/knee replacement used

CPT code	description
27130	Total Hip Replacement/Resurfacing
27132	Total Hip Replacement/Resurfacing
81.51	Total hip replacement
0SR9	Replacement: Hip Joint, Right
0SRB	Replacement: Hip Joint, Left
27442	Knee Total Replacement - (Arthroplasty)
27443	Knee Total Replacement - (Arthroplasty)
27445	Knee Total Replacement - (Arthroplasty)
27446	Knee Total Replacement - (Arthroplasty)
27447	Knee Total Replacement - (Arthroplasty)
81.54	Total knee replacement
0SRC	Replacement: Knee Joint, Right
0SRD	Replacement: Knee Joint, Left

Table S3: Codes used to determine RCRI

Description	Constituent Codes (*NDC: National Drug Code)
History of Heart Failure	ICD9 codes: 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9, 428.2, 428.3, 428.4; ICD10 codes: I50.1, I50.20, I50.21, I50.22, I50.23, I50.30, I50.31, I50.32, I50.33, I50.40, I50.41, I50.42, I50.43, I50.810, I50.811, I50.812, I50.813, I50.814, I50.82, I50.83, I50.84, I50.89, I50.9, I50.2, I50.3, I50.4, I50.8, I50.81
History of Cerebrovascular Disease	ICD9 codes: 430, 431, 432.0, 432.1, 432.9, 433.00, 433.01, 433.10, 433.11, 433.20, 433.21, 433.30, 433.31, 433.80, 433.81, 433.90, 433.91, 434.00, 434.01, 434.10, 434.11, 434.90, 434.91, 435.0, 435.1, 435.2, 435.3, 435.8, 435.9, 436, 437.0, 437.1, 437.2, 437.3, 437.4, 437.5, 437.6, 437.7, 437.8, 437.9, 438.0, 438.10, 438.11, 438.12, 438.13, 438.14, 438.19, 438.20, 438.21, 438.22, 438.30, 438.31, 438.32, 438.40, 438.41, 438.42, 438.50, 438.51, 438.52, 438.53, 438.6, 438.7, 438.81, 438.82, 438.83, 438.84, 438.85, 438.89, 438.9, 432, 433, 434, 435, 437, 438, 433.0, 433.1, 433.2, 433.3, 433.8, 433.9, 434.0, 434.1, 434.9, 438.1, 438.2, 438.3, 438.4, 438.5, 438.8; ICD10 codes: I60.00, I60.01, I60.02, I60.10, I60.11, I60.12, I60.2, I60.30, I60.31, I60.32, I60.4, I60.50, I60.51, I60.52, I60.6, I60.7, I60.8, I60.9, I61.0, I61.1, I61.2, I61.3, I61.4, I61.5, I61.6, I61.8, I61.9, I62.00, I62.01, I62.02, I62.03, I62.1, I62.9, I63.00, I63.011, I63.012, I63.013, I63.019, I63.02, I63.031, I63.032, I63.033, I63.039, I63.09, I63.10, I63.111, I63.112, I63.113, I63.119, I63.12, I63.131, I63.132, I63.133, I63.139, I63.19, I63.20, I63.211, I63.212, I63.213, I63.219, I63.22, I63.231, I63.232, I63.233, I63.239, I63.29, I63.30, I63.311, I63.312, I63.313, I63.319, I63.321, I63.322, I63.323, I63.329, I63.331, I63.332, I63.333, I63.339, I63.341, I63.342, I63.343, I63.349, I63.39, I63.40, I63.411, I63.412, I63.413, I63.419, I63.421, I63.422, I63.423, I63.429, I63.431, I63.432, I63.433, I63.439, I63.441, I63.442, I63.443, I63.449, I63.49, I63.50, I63.511, I63.512, I63.513, I63.519, I63.521, I63.522, I63.523, I63.529, I63.531, I63.532, I63.533, I63.539, I63.541, I63.542, I63.543, I63.549, I63.59, I63.6, I63.81, I63.89, I63.9, I65.01, I65.02, I65.03, I65.09, I65.1, I65.21, I65.22, I65.23, I65.29, I65.8, I65.9, I66.01, I66.02, I66.03, I66.09, I66.11, I66.12, I66.13, I66.19, I66.21, I66.22, I66.23, I66.29, I66.3, I66.8, I66.9, I67.0, I67.1, I67.2, I67.3, I67.4, I67.5, I67.6, I67.7, I67.81, I67.82, I67.83, I67.841, I67.848, I67.850, I67.858, I67.89, I67.9, I68.0, I68.2, I68.8, I69.00, I69.010, I69.011, I69.012, I69.013, I69.014, I69.015, I69.018, I69.019, I69.020, I69.021, I69.022, I69.023, I69.028, I69.031, I69.032, I69.033, I69.034, I69.039, I69.041, I69.042, I69.043, I69.044, I69.049, I69.051, I69.052, I69.053, I69.054, I69.059, I69.061, I69.062, I69.063, I69.064, I69.065, I69.069, I69.090, I69.091, I69.092, I69.093, I69.098, I69.10, I69.110, I69.111, I69.112, I69.113, I69.114, I69.115, I69.118, I69.119, I69.120, I69.121, I69.122, I69.123, I69.128, I69.131, I69.132, I69.133, I69.134, I69.139, I69.141, I69.142, I69.143, I69.144, I69.149, I69.151, I69.152, I69.153, I69.154, I69.159, I69.161, I69.162, I69.163, I69.164, I69.165, I69.169, I69.190, I69.191, I69.192, I69.193, I69.198, I69.20, I69.210, I69.211, I69.212, I69.213, I69.214, I69.215, I69.218, I69.219, I69.220, I69.221, I69.222, I69.223, I69.228, I69.231, I69.232, I69.233, I69.234, I69.239, I69.241, I69.242, I69.243, I69.244, I69.249, I69.251, I69.252, I69.253, I69.254, I69.259, I69.261, I69.262, I69.263, I69.264, I69.265, I69.269, I69.290, I69.291, I69.292, I69.293, I69.298, I69.30, I69.310, I69.311, I69.312, I69.313, I69.314, I69.315, I69.318, I69.319, I69.320, I69.321, I69.322, I69.323, I69.328, I69.331, I69.332, I69.333, I69.334, I69.339, I69.341, I69.342, I69.343, I69.344, I69.349, I69.351, I69.352, I69.353, I69.354, I69.359, I69.361, I69.362, I69.363, I69.364, I69.365, I69.369, I69.390, I69.391, I69.392, I69.393, I69.398, I69.80, I69.810, I69.811, I69.812, I69.813, I69.814, I69.815, I69.818, I69.819, I69.820, I69.821, I69.822, I69.823, I69.828, I69.831, I69.832, I69.833, I69.834, I69.839, I69.841, I69.842, I69.843, I69.844, I69.849, I69.851, I69.852, I69.853, I69.854, I69.859, I69.861, I69.862, I69.863, I69.864, I69.865, I69.869, I69.890, I69.891, I69.892, I69.893, I69.898, I69.90, I69.910, I69.911, I69.912, I69.913, I69.914, I69.915, I69.918, I69.919, I69.920, I69.921, I69.922, I69.923, I69.928, I69.931, I69.932, I69.933, I69.934, I69.939, I69.941, I69.942, I69.943, I69.944, I69.949, I69.951, I69.952, I69.953, I69.954, I69.959, I69.961, I69.962, I69.963, I69.964, I69.965, I69.969, I69.990, I69.991, I69.992, I69.993, I69.998, I60, I61, I62, I63, I65, I66, I67, I68, I69, I60.0, I60.1, I60.3, I60.5, I62.0, I63.0, I63.1, I63.2, I63.3, I63.4, I63.5, I63.8, I65.0, I65.2, I66.0, I66.1, I66.2, I67.8, I69.0, I69.1, I69.2, I69.3, I69.8, I69.9, I63.01, I63.03, I63.11, I63.13, I63.21, I63.23, I63.31, I63.32, I63.33, I63.34, I63.41, I63.42, I63.43, I63.44, I63.51, I63.52, I63.53, I63.54, I67.84, I67.85, I69.01, I69.02, I69.03, I69.04, I69.05, I69.06, I69.09, I69.11, I69.12, I69.13, I69.14, I69.15, I69.16, I69.19, I69.21, I69.22, I69.23, I69.24, I69.25, I69.26, I69.29, I69.31, I69.32, I69.33, I69.34, I69.35, I69.36, I69.39, I69.81, I69.82, I69.83, I69.84, I69.85, I69.86, I69.89, I69.91, I69.92, I69.93, I69.94, I69.95, I69.96, I69.99
History of Ischemic Heart Disease	ICD9 codes: 410.00, 410.01, 410.02, 410.10, 410.11, 410.12, 410.20, 410.21, 410.22, 410.30, 410.31, 410.32, 410.40, 410.41, 410.42, 410.50, 410.51, 410.52, 410.60, 410.61, 410.62, 410.70, 410.71, 410.72, 410.80, 410.81, 410.82, 410.90, 410.91, 410.92, 411.0, 411.1, 411.81, 411.89, 412, 413.0, 413.1, 413.9, 414.00, 414.01, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 414.10, 414.11, 414.12, 414.19, 414.2, 414.3, 414.4, 414.8, 414.9, 410, 411, 413, 414, 410.0, 410.1, 410.2, 410.3, 410.4, 410.5, 410.6, 410.7, 410.8, 410.9, 411.8, 414.0, 414.1; ICD10 codes: I20.0, I20.1, I20.8, I20.9, I21.01, I21.02, I21.09, I21.11, I21.19, I21.21, I21.29, I21.3, I21.4, I21.9, I21.A1, I21.A9, I22.0, I22.1, I22.2, I22.8, I22.9, I23.0, I23.1, I23.2, I23.3, I23.4, I23.5, I23.6, I23.7, I23.8, I24.0, I24.1, I24.8, I24.9, I25.10, I25.110, I25.111, I25.118, I25.119, I25.2, I25.3, I25.41, I25.42, I25.5, I25.6, I25.700, I25.701, I25.708, I25.709, I25.710, I25.711, I25.718, I25.719, I25.720, I25.721, I25.728, I25.729, I25.730, I25.731, I25.738, I25.739, I25.750, I25.751, I25.758, I25.759, I25.760, I25.761, I25.768, I25.769, I25.790, I25.791, I25.798, I25.799, I25.810, I25.811, I25.812, I25.82, I25.83, I25.84, I25.89, I25.9, I20, I21, I22, I23, I24, I25, I21.0, I21.1, I21.2, I21.A, I25.1, I25.4, I25.7, I25.8, I25.11, I25.70, I25.71, I25.72, I25.73, I25.75, I25.76, I25.79, I25.81
Pre-operative creatinine $>$ 2 mg/dL / 176.8 µmol/L - Approximated by History of Chronic Kidney Disease	ICD9 codes: 585.3, 585.5, 585.6, 585.4; ICD10 codes: N18.30, N18.31, N18.32, N18.4, N18.5, N18.6, N18.3
Pre-operative treatment with Insulin	NDC* codes: 08881242112, 08881250305, 54868582400, 08881750023, 08881242120, 08881250313, 38396043277, 08881250321, 00169369619, 08881520665, 08881242138, 36652040218, 56151171101, 08881520673, 08496275501, 08881250354, 08496275511, 08881250362, 08080810055, 36652040276, 00002831101, 08080040028, 08080040029, 08080040030, 08396800100, 38396043377, 08881750130, 36652040318, 00002831517, 56151171201, 08881750155, 08881512597, 36652400801, 36652400802, 36652400803, 36652400804, 36652400805, 36652400806, 36652400807, 36652400808, 68258889903, 08881103025, 36652040376, 96295010494, 96295010495, 96295010496, 96295010497, 96295010498, 08881512647, 08396800200, 38396043477, 57515008218, 08881750239, 56151171301, 08881750254, 55948009710, 08881250545, 57515008258, 36652400901, 36652400902, 36652400903, 36652400904, 36652400905, 08080032010, 36652400906, 36652400907, 36652400908, 59060183302, 08881512738, 08881512746, 08396800300, 54569165101, 08881701166, 54569165102, 38396076339, 08881701174, 54274048310, 08290328888, 38396043577, 08222073150, 08881750338, 08222032195, 96295010629, 36652040518, 08881676624, 96295010643, 08881906005, 96295010645, 08881676632, 08881701216, 00002821001, 08881701224, 59060183402, 08881512811, 08080032110, 08222073198, 36652040576, 89134072202, 00002831501, 08396800400, 54569165200, 54569165202, 08881512852, 54274048410, 08881512860, 38396043677, 51927368100, 36652040618, 08881512878, 08881906104, 57515082180, 08080327114, 08080032210, 36652040676, 08881750510, 52297086578, 08881512944, 08287126003, 08287126004,

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Pre-operative treatment with Insulin (contd.)	NDC* codes: 08287126005, 08396800500, 08881701364, 08415003129, 08415003130, 08287126014, 08287126015, 08287126016, 38396043777, 08287126021, 08287126026, 08287126027, 08287126028, 08287126029, 36652040718, 08222073358, 08881512977, 08881701406, 08080622112, 00002841501, 00888160813, 08222073396, 08290009652, 08080032310, 08881513025, 68258898501, 36652040776, 08881513033, 89134072402, 08396800600, 08326300250, 08474935900, 08881513058, 38396043877, 11845026407, 36652040818, 08080827012, 59060183702, 08474010278, 68258898601, 08881513132, 08881750700, 36652040876, 54868361900, 08396800700, 08881750718, 08881513157, 38396043977, 08222032591, 08222073556, 08881608201, 08881608202, 08881608203, 08881513207, 08222073594, 08080032510, 08881513223, 08474010378, 08881513231, 11917001487, 11917001489, 11917001492, 54569255700, 54569255701, 08396800800, 08881513249, 08881120037, 08881513256, 76300084010, 00169001771, 38396044077, 08290329403, 08290329405, 08290329406, 08290329407, 08290329408, 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Pre-operative treatment with Insulin (contd.)	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Pre-operative treatment with Insulin	NDC* codes: 08290843801, 08881601689, 08290843803, 56151170201, 08881601697, 08881200292, 08881601705, 08881700010, 08881601713, 08881601721, 08881200318, 08881200326, 08496315601, 08881601747, 08881200342, 08881601762, 00536993001, 08881601770, 59060231404, 38396042490, 54569295100, 54569295101, 56151170301, 08881200383, 08881716503, 54868131100, 08881716511, 87701445930, 08881200433, 08881716529, 08881601846, 08881200441, 08881716537, 08881601853, 08881601861, 08881020233, 54868589900, 08881200466, 08881601879, 08290008410, 08290008411, 00182312285, 38396042590, 00182312288, 08290844001, 08290008430, 08290008431, 87701044593, 08881200508, 08222072191, 00904396160, 36652400001, 36652400002, 36652400003, 08881200516, 36652400004, 36652400005, 36652400006, 36652400007, 36652400008, 08290008465, 08290008466, 08881200573, 00839802306, 38396042690, 00069070737, 08881135068, 54868532700, 54868532701, 36652400101, 36652400102, 36652400103, 36652400104, 36652400105, 36652400106, 36652400107, 36652400108, 08881135084, 08214502901, 00002841101, 59060231704, 00839802406, 38396042790, 08080621100, 00002821601, 08881520178, 08080621112, 08881700408, 08881520186, 00002824001, 00002821517, 08881200714, 36652400202, 36652400203, 36652400205, 36652400206, 36652400207, 36652400208, 08222072399, 00169033301, 00002879359, 08214503001, 00169352815, 08881200755, 08881520251, 00839802506, 08290328203, 38396042890, 08080826012, 00003183715, 38396042912, 08881200805, 08290328233, 08496291501, 54868238001, 08881716917, 08496291511, 08881847993, 08290328278, 08290328279, 08290328280, 08290328281, 08290328282, 08290328283, 08290320096, 08290328289, 08290328290, 08290328291, 08881250016, 08881250024, 08881676012, 08290320109, 00839802606, 38396042990, 08881250032, 08290320119, 08881250040, 54868623100, 08080826112, 38396043012, 08214355719, 08881250057, 00002811201, 08881250065, 08222072597, 08881250073, 08881250081, 68258897701, 08881250099, 08881250107, 08881512258, 08881250115, 08881250123, 38396043090, 08881250131, 08290328410, 08290328411, 08290328412, 08290328418, 08881250149, 38396043112, 08290328430, 08290328431, 08881250164, 08290328438, 08290328440, 08881250172, 08881250180, 08881053577, 08290320271, 08290328465, 08290328466, 08290328468, 08881250198, 08290328471, 00002854001, 08881250206, 08881250214, 38396043177, 08881250222, 08881070001, 08080818100, 08080818101, 08881250230, 38396043190, 68115070905, 08080818112, 08080818113, 08881250248, 08881250255, 08080220112, 08881250263, 08881160157, 08881250271, 08881242088, 08881250289, 08881750007

Table S4: ICD codes for myocardial infarction used to identify positive cohort

ICD code	description
I46.8	Cardiac arrest due to other underlying condition
I21	ST elevation (STEMI) myocardial infarction involving left main coronary artery
410.72	Subendo infarct subseq
I21.01	ST elevation (STEMI) myocardial infarction involving left main coronary artery
410.01	AMI anterolateral init
I21.4	Non-ST elevation (NSTEMI) myocardial infarction
I21.A9	Other myocardial infarction type
I21.A1	Myocardial infarction type 2
410.61	True post infarct init
I21.3	ST elevation (STEMI) myocardial infarction of unspecified site
410.8	AMI NEC unspecified
410.42	AMI inferior wall subseq
427.5	Cardiac arrest
I46	Cardiac arrest due to underlying cardiac condition
I46.2	Cardiac arrest due to underlying cardiac condition
410	AMI anterolateral unspec
410.71	Subendo infarct initial
410.11	AMI anterior wall init
410.12	AMI anterior wall subseq
410.7	Subendo infarct unspec
I21.21	ST elevation (STEMI) myocardial infarction involving left circumflex coronary artery
410.4	AMI inferior wall unspec
410.21	AMI inferolateral init
410.82	AMI NEC subsequent
410.9	AMI NOS unspecified
410.2	AMI inferolateral unspec
I21.9	Acute myocardial infarction unspecified
I46.9	Cardiac arrest cause unspecified
410.1	AMI anterior wall unspec
410.02	AMI anterolateral subseq
410.51	AMI lateral NEC initial
410.52	AMI lateral NEC subseq
410.92	AMI NOS subsequent
I21.02	ST elevation (STEMI) myocardial infarction involving left anterior descending coronary artery
I21.19	ST elevation (STEMI) myocardial infarction involving other coronary artery of inferior wall
410.81	AMI NEC initial
410.41	AMI inferior wall init
410.31	AMI inferopost initial
410.62	True post infarct subseq
I21.09	ST elevation (STEMI) myocardial infarction involving other coronary artery of anterior wall
410.0	AMI anterolateral unspec
410.5	AMI lateral NEC unspec
410.6	True post infarct unspec
410.3	AMI inferopost unspec
410.91	AMI NOS initial
410.32	AMI inferopost subseq
I21.11	ST elevation (STEMI) myocardial infarction involving right coronary artery
410.22	AMI inferolateral subseq
I21.29	ST elevation (STEMI) myocardial infarction involving other sites

Table S5: Number of diagnostic codes encountered in dataset

gender	Number of codes	Number of unique codes
M	4879398	17554
F	7753318	19209
Total	12632716	36763

Table S6: CCoR phenotypes and maximum number of unique ICD codes defining CCoR phenotypes

CCoR phenotype	**count of ICD codes in definition (Table S7)**
Allergic	191
Cardiovascular	2017
CNS	765
Development	820
Digestive	1317
Endocrine	237
Frailty	557
Health-Services	501
Hematologic	429
Hypertension	80
Immune	1546
Infections-Bacterial	409
Infections-Fungal-and-Other	784
Infections-General	3612
Infections-Respiratory	712
Injuries	53265
Integumentary	1457
Metabolic	373
Musculoskeletal	7533
Neoplastic	3022
Ophthalmological	3401
Otic	856
PNS	394
Psychiatric	1478
Reproductive	2675
Respiratory	724

Table S7: Disease Categories With Detailed Set of ICD Codes Used in Definition. Not all infection and injury codes have been listed here.

	Description	Constituent ICD9 Codes
Allergic		477.2 493.81 T50.995A J67.2 495.6 T78.03x 372.14 J67 J67.0 M13.89 J30.1 995.63 995.65 558.3 T45.0X1A M13.859 716.27 D29.30 D29.1 L27.2 477.9 495.5 493.22 D69.2 T78.00x 287.33 995.60 J45.31 J45.51 D29.20 J67.7 T78.09xA D29.22 M13.80 J30.9 T78.08x 287.8 H10.45 B44.81 716.20 995.61 T78.05xA 493.92 693.1 493.90 T78.40x J45.20 493.82 J45.40 D69.42 495.7 J67.5 493.20 D69.49 J45.32 287.32 708.0 H65.119 995.64 D69.1 J45.21 D69.6 M13.819 716.23 495.4 995.67 287.1 T78.08xA T78.00xA 477.0 493.02 525.66 T78.02xA J67.1 D69.3 T78.04x T78.2xxA D29.4 716.25 T78.07xA 716.26 T78.07x M13.88 J67.3 495.9 J45.30 493.21 477 495.2 995.62 T78.40xA 995.27 287.2 495.8 495 287.5 995.0 493 T78.05x L50.0 493.11 J45.902 D29.0 J45.990 287.9 J45 D29.21 J30.0 963.0 495.1 D29.32 L25.9 J44.9 J44.0 477.1 M13.879 493.01 J45.41 T50.995 J45.998 692.9 M13.849 995.66 D69.8 995.69 T78.04xA J30 495.3 M13.869 287.30 J45.991 J44.1 995.3 287.4 J45.52 287.0 381.06 716.21 J45.901 J67.4 287.39 493.91 373.32 287.31 T78.06xA J30.89 287 K08.55 K52.2 D29.31 J45.50 495.0 J67.6 D69.9 D29.8 T78.02x 716.24 477.8 381.05 D29 493.12 T78.03xA J67.9 716.22 T78.2xx J30.5 999.4 493.00 M13.829 T78.01x T78.06x 493.10 518.6 716.28 J30.2 H01.119 995.68 M13.839 D69.0 T78.09x 381.04 D29.9 T78.01xA 716.29 J30.81 J45.22 J45.42 T45.0X1 J45.909 D69.41 J67.8
Cardiovascular		I35.0 I48.0 I25.728 444.8 P29.38 I94 I63.212 402.00 I70.669 440.30 I89.9 I60.9 I20.1 413.9 I24.1 I80.3 415.1 I77.811 785.9 I69.319 I69.339 I82.5Z9 R04.1 429.6 G43.619 I82.503 I82.611 I70.512 I75.011 I69.834 I70.628 K64.9 I89.0 I21.09 428.42 447.5 442.8 I70.792 454.0 I70.318 I50.83 I70.744 405.0 426.2 455 I70.442 455.3 I82.B29 I12 415 433.8 I69.320 I27.81 444.21 I70.735 I82.602 I67.89 441.4 425.4 I35.9 I70.693 I69.234 I65.23 427.2 I70.244 I49.02 I82.91 P29.89 I70.719 I69.131 I36.8 I60.8 I60.11 442.82 I69.852 I75.029 438.22 I69.120 I70.641 I60.2 426.51 I70.302 417.9 I63.012 R04.2 R00.2 427.31 I25.718 I05.8 I70.791 I89 426.50 I63.349 I49.49 444.89 I63.213 I83.12 I77.0 I82.433 I70.608 P29 I47.1 428 I70.348 I82.C29 I82.532 I69.322 I63.311 I65.03 I82.291 I70.498 I97.791 I69.859 I70.644 I82.441 I63.413 I70.362 405.11 I62 I87.012 I80.292 411.1 433 I70.532 I97.638 I87.091 I69.998 I07.8 I11.9 I69.390 445.01 I69.223 I37.2 I87.319 I69.932 I70.208 I82.492 I82.891 I63.233 I70.319 I70.65 I70.341 435 441.9 I40.0 I63.539 K64.4 I95.89 I69.028 I82.5Y9 I50.32 I70.731 I70.768 458.0 G43.601 I21.01 410.71 429.3 I69.398 I87.399 441.0 I70.421 I73 I70.729 E86.0 I69.231 I28.8 I13.0 I70.568 I42.2 I63.431 411.89 I70.709 438.21 438.53 I70 I50.84 I42.0 I70.212 I77.74 I08.0 P29.2 455.0 410.1 416.1 I24.8 433.10 I70.393 413.1 I70.561 I87.092 I83.218 427.60 453.82 I70.534 I97.130 I97.821 I97.711 I63.543 I02.0 405.01 I69.364 I07 I83.92 I69.928 I69.214 I70.418 346.63 I06.8 410.60 I31.2 I70.433 I75.013 I70.219 I70.431 I75.023 I82.403 I83.10 I25.730 415.13 I13.2 I69.814 I50.812 I79 429.89 I69 I69.833 I23 410.20 I77.6 I69.165 I60.52 459.81 I47 410.10 I83.201 I82.419 I69.033 I15.9 404.0 I69.213 441.7 I82.412 I69.261 I82.432 417 I24.9 I69.315 438.19 I72.8 I36.2 I97.648 I70.539 I56 I69.392 I63.512 I69.820 I77.70 I63.00 I70.439 I70.643 433.80 276.50 459.3 I70.522 I69.121 433.21 426.4 346.61 I61 I75.021 I88.8 I55 785.1 I01.9 I25.729 I63.20 454.9 I63.521 I70.769 I69.334 I72.4 I50.31 438.50 434 I70.349 I48.2 435.1 I80.219 I10 I69.115 I70.544 414.00 I69.010 I66.12 445.8 I30.9 I27.1 I80.293 432 I97.190 I69.864 I86 I34.1 410.8 438.9 I63.133 I25.89 I63.032 I34.8 I77.4 I82.4Z2 I87.391 411.0 I87.312 440.4 I63.232 I87.009 R00.8 I69.012 I70.468 Q82.5 I21.3 I87.303 I25.6 I69.842 290.41 455.8 I69.042 I82.C23 I87.099 I69.314 I74.10 I77.812 I69.393 I42.5 I69.141 I70.491 I82.210 785.50 I69.351 I82.513 785 I69.252 785.52 I77.819 415.11 I80.13 I71.5 I82.422 I42.6 P29.30 I69.031 I70.222 I31.4 I82.603 I82.729 437 I70.621 I70.509 I70.763 I95 I38 433.3 I69.133 K55.0 426.6 I80.212 I70.723 I70.229 404.10 I83.029 437.3 426.13 I65.22 I75.012 I80.202 I48.3 I27.83 I69.815 I75.022 I27.20 I70.711 453 I65.9 I80.233 410.01 I70.291 440.2 I63.29 404.11 I82.A21 R04.89 I08.3 785.0 438.10 I70.469 I91 I69.163 447.2 I50.1 414.4 I83.002 410.5 I70.243 I63.039 I70.249 I70.269 I80.211 I86.8 I70.499 I69.363 404.02 I22.0 I69.211 458.2 I83.213 I83.028 I74.2 428.0 I70.545 442 443.89 426.3 I69.362 I31 I70.398 I81 I69.810 I70.261 443.22 I70.1 I70.335 I92 I77.89 I60.00 I83.203 I72.3 I63.532 410.2 I71.02 I70.331 441.03 I69.262 410.6 I65.29 I54 453.71 I69.293 438.81 I69.110 I15 R65.21 428.31 453.89 I69.051 I67.7 I69.062 I69.111 I69.349 454.1 453.1 I63.39 I82.1 I66.03 I72 I46.8 426.12 I45.81 I73.1 I70.634 I69.918 I95.1 I87.393 410.02 410.0 I70.332 I82.549 443.29 I77.5 440 I31.8 I21 I82.B23 I11.0 433.01 455.7 403.00 I66.02 438.14 I06.0 G45.0 I97.51 I69.112 I70.369 I82.5Y2 I45.2 I74.01 415.19 I87.311 I63.22 I84 I20 I70.203 I83.009 I87 I71 433.1 I06.1 456.4 I69.822 I99 I33.0 I70.218 438.5 I60.10 I69.254 413 I51.2 I69.065 I59 410.62 I07.2 I80.8 I96 453.76 437.2 435.3 414.11 I83.019 I09.2 I83.93 426.81 I63.323 410.72 435.2 I63.441 I83.011 410.31 I82.B11 410.81 I27.23 438.41 I75.81 404.9 I13.11 I66.09 I95.0 I83.022 438.4 I82.431 I70.202 I70.342 I70.648 I23.3 I69.265 437.9 I82.812 I82.439 I63.59 I97.120 I69.249 I07.9 455.6 I82.501 I82.A23 I74.09 I63.329 I70.722 I82.423 I87.9 I82.C21 414.02 I42.9 I69.093 404 I24 455.9 I32 I70.798 I44.60 441.02 R04 I50.40 I87.302 I82.509 441 I77.3 I97.630 I69.993 I53 I83 I82.499 I69.034 I70.402 I60.01 458.1 438.82 I24.0 458 I69.144 R01.2 I70.231 I65.1 I70.429 I70.612 I50.33 I82.612 I63.422 I57 433.2 I69.221 I95.9 I78 I97.111 I04 I69.963 779.82 410.52 410.3 I70.298 438.20 I48 I50.82 I70.698 I70.533 I69.915 I69.052 425.9 I69.243 I80.229 427.32 438 410.41 I69.092 413.0 290.4 I27.22 I69.043 442.83 453.86 557 453.75 445.0 I23.2 438.1 458.21 I70.303 I70.541 I70.201 I69.154 411 429.1 I51.9 I60.7 I69.244 427.41 I72.6 I16.0 290.42 I70.793 I82.491 I69.022 443.8 I51.5 I26.09 I83.225 I37.9 I66.13 I70.329 I69.191 I70.638 444.2 I36.1 I69.91 R01.1 I08.1 I70.333 I70.462 I82.401 I82.A19 I63.519 K55.9 I82.4Y3 I82.5Z3 I33 410.7 I45.4 I69.333 I83.219 I69.198 I70.399 426.54 I25.710 442.81 557.9 I80.231 I82.443 I80.01 P29.12 447.3 I70.245 410.70 433.91 I69.812 I50.23 448.9 434.9 I26.99 427.5 I77.77 453.6 I69.118 I35 441.3 I82.C22 I08.8 414.07 I28.0 438.89 I97.42 I65.09 I37.0 I67.848 I70.449 I77.2 411.8 I70.603 G45.4 453.81 I44.5 426.0 I06.2 I74.5 427.9 427.42 I70.213 I61.2 444.9 I62.1 F01.51 I70.701 456.8 456 I87.013 I01.8 440.3 453.83 I69.242 I42.1 I83.811 I69.069 I69.313 I83.023 I45.9 I69.013 I69.813 453.77 I21.11 I25.82 I87.339 I70.749 I83.892 I23.5 I97.611 I66.3 I63.449 453.72 I88.0 405.9 I69.059 I40 I69.943 I70.748 I21.02 428.32 447.70 I78.8 403.9 I82.521 I69.321 405.09 453.40 I63.9 I69.854 453.42 I40.8 I69.162 426.1 I69.192 I83.222 I87.033 I25.83 I74.3 I82.523 458.9 K64.8 438.83 I42.7 I70.521 459 I83.221 I82.609 I82.703 I07.0 I97.110 I69.942 437.6 405.1 I60.6 I69.342 I70.728 405.99 I69.831 I69.30 I12.9 438.3 447.71 441.00 I69.828 434.91 I09.89 I23.4 I83.024 I47.0 I82.543 I50.810 I70.293 I82.211 405.19 I86.2 I69.954 I70.409 I83.812 I97.622 437.0 I25.799 403.01 I75.89 I50.20 I63.533 I78.1 428.33 I82.A22 I79.0 414 402 414.01 427.89 I69.964 I70.642 I63.542 I47.2 I87.309 I63.339 I77.72 I70.363 414.06 404.92 I71.2 441.1 I82.522 I20.8 402.11 I82.819 I65.8 I36.9 I99.9 785.3 429 I69.344 I97.811 I63.113 443.21 I69.020 I70.328 I72.9 I62.01 I70.613 447.72 I82.542 785.51 I69.132 I83.015 I82.493 I67.4 426.52 425.7 I80.00 I70.338 I63.30 I78.9 I74.19 I87.392 442.9 I82.449 I69.862 403.90 402.10 I25.758 402.1 I27.21 I83.202 I86.0 I70.401 I87.093 I49.8 I95.3 433.11 I02.9 425.2 I70.519 412 I70.739 I70.702 404.03 429.5 I88.9 410 I82.B21 410.22 I69.169 I70.368 429.82 I82.619 I82.592 I60 437.8 I80.10 414.0 433.9 I72.5 I70.591 404.12 I69.219 I73.9 I46 I63.50 434.1 I82.599 I74.9 I83.018 I82.4Z9 I70.392 I66.11 I63.531 I70.435 I22.2 I65.02 I82.541 425.0 I69.298 I63.40 I69.263 I95.81 453.8 I82.409 R03.1 I25.759 I87.1 I69.353 434.01 557.1 I25.2 I70.598 I70.601 I79.1 R57.8 I63.131 I22 414.03 I46.2 I19 I63.439 403.91 I69.064 429.8 426.9 I63.09 I80.03 I45.89 I97 I82.531 429.79 I13 I69.032 I22.8 I26.90 434.10 415.12 I70.639 I69.232 I51.0 I60.51 I63.411 I97.131 I69.891 I70.8 I44.0 I39
CNS		346.32 335.10 G40.019 G47.54 G43.609 G44.029 G16 344 349.2 G47.20 G45.0 G21.4 347.00 G81.11 346.82 G95.19 G47.27 345.70 347.11 G25.89 341.21 322 344.30 346.93 G04.2 G40.909 G40.219 G43.619 G80.0 327.15 G43.011 333.1 349.82 327.51 G83.10 G12 G47.35 327.32 G03.8 327.41 337.00 G46.2 G96.12 G05.4 G43.101 G24.2 G47.29 G12.21 345.00 G93.1 346.72 G13.1 G95.9 331.7 G31.01 343.8 G40.209 346.40 334.9 G30.1 G44.309 G83.13 321.0 344.89 G47.23 G44.009 G11.9 324.9 G43.D0 G81.90 346.20 G03.1 333.84 320.1 348.30 G30 G81.93 G95.0 G37.5 G47.12 G25.71 327.29 G40.201 346.41 G06.2 G37.9 767.0 G40.813 P91.63 G93.49 344.9 345.01 334 G47.52 322.9 G44.41 336.1 G44.82 335.11 348.39 G47.22 G37.2 G46.0 327.11 G04.89 G22 331 G41 G43.509 G83.30 327.30 G93.7 333.2 333.5 G47.419 344.41 P91.2 P91 328 349.1 G90.529 G25.79 344.5 G40.111 337.20 G83.89 G37.1 348.4 G23.2 G25.1 G44.81 G00.2 G40.804 G40.B09 336 G44.83 G47.00 G82.50 344.60 337 343 G47.63 327.44 G44.40 336.9 G13.8 P91.1 333.82 G47.59 G31.1 G82.20 334.2 333.71 G35 G21.0 G24.1 G25.3 G23 G46.5 322.0 327.8 779.2 333.85 G25.0 G81.01 344.04 G43.C1 G44.53 G40.814 G00.3 G43.111 342.02 333.89 G23.1 G90.59 G80.2 F51.05 G91.0 G40.823 343.4 344.01 335.20 G40.411 G44.221 G47.14 G12.25 G04 343.3 G43.A0 333.79 327.22 346.01 G18 G03 G83.9 G40.409 G44.001 331.82 323.42 323.72 G82.53 337.3 G93.40 G99.0 G43.719 E75.4 G40.009 G47.30 G47.10 G40.802 336.0 327.01 G40.B01 P91.60 323.63 340 G43.B1 345.91 P52.8 G12.8 G43.419 G07 G93.9 G40.001 327.40 G44.209 337.1 G25.4 G99.2 333 333.72 323.81 327.23 323.02 344.2 G12.24 333.4 327.59 G12.23 G43.601 331.2 333.3 G83.4 G44.219 G40.101 B45.1 330.0 G44 G83.23 G93.2 G43.001 G43.C0 327.49 G21.8 G46.7 G30.9 G40.419 G82.52 G40.A01 345.61 347 G44.321 G11.8 G00.9 330.1 G43.B0 G44.011 323.1 G31.81 G43.401 320.89 G83.20 346.80 G47.9 G43.911 G47.62 348.9 G13.2 346.90 G47.31 G90.09 335 342.82 327.20 342.11 G11.2 327.19 346.02 341 G40.119 G47.09 322.1 G04.02 G19 348.5 G43.829 323.82 333.99 342.12 345.3 G40.011 G20 G45.9 G40.89 P91.0 346.42 346.60 335.23 G03.9 G40.309 336.3 333.90 349 G04.01 346.00 327.14 342 G05.3 G44.059 321.2 G31.89 G43.701 G37 G43.511 G40.822 G43.919 G44.51 G47.36 345.41 G31.2 G13.0 G91.1 344.31 G00.0 320.2 G25.81 344.61 G44.329 G47.429 G40.824 G80.8 346.63 G46 G30.8 G43.831 G80.3 348.2 333.83 G45.4 G13 320.0 345.10 344.40 341.1 G37.3 G31 G14 333.94 G24.3 G36.9 G45.2 349.39 G24.8 G47 G04.31 G05 G11.4 341.20 332.1 344.1 G47.39 G83.5 G46.1 G25.70 G21.19 G00.1 343.9 G25.61 G40.311 G21 331.11 G32.89 G47.51 332.0 335.22 G44.091 345.80 331.81 G36.8 G00.8 G46.8 G47.34 P91.88 G43.D1 323.71 330.9 G04.90 331.89 G06.1 G46.4 348.1 346.30 G43.019 G82.54 337.29 335.8 G04.1 337.22 G43.839 344.02 327.43 G12.1 G43.901 G47.69 G10 G47.421 G47.50 G44.84 G31.83 346.62 G47.01 345 G47.19 G44.031 G25 320.7 323.51 G33 G06.0 G32.81 346.50 G83.11 G27 337.09 G24.09 322.2 344.00 346.61 G43.801 327.37 G31.85 327.42 G36 346.31 G46.3 G24.9 G40.211 G24.01 327.26 G44.049 341.9 G44.039 327.33 346.83 334.1 335.29 344.09 323.2 346.13 327.12 G47.37 327.36 327.02 G43.909 G25.5 G40.803 346.12 G12.20 327.31 G37.8 345.2 327.10 G44.311 G43.409 344.42 343.0 G06 323.01 333.93 346.81 G40.509 325 G44.211 G43 G81.00 G93.0 341.8 335.0 G09 G96.9 320.81 G44.229 G04.32 G24.4 346.11 G25.69 333.6 G37.4 G04.81 G44.201 345.81 332 G12.22 346.51 346.33 331.5 342.90 G44.099 G40.401 G95.89 346.10 F51.13 G43.501 G01 334.4 324 327.13 G44.051 345.71 327.53 320.3 345.60 G12.0 G04.91 G44.85 G43.821 G97.41 G11.0 346.21 P91.62 G39 345.51 321.1 G96.11 323.62 G80.1 G43.009 G31.82 344.81 327 G43.519 346.23 G43.119 336.8 345.40 345.50 333.0 G81.10 348.89 326 345.90 327.24 333.92 G29 334.0 G40.301 G47.24 G43.711 G44.021 G46.6 G40.319 333.91 G04.30 G43.A1 G31.84 G43.411 G32.0 337.01 G04.00 G21.9 P91.61 G47.26 346.43 G44.52 G83.21 G38 344.32 327.34 346.71 P91.811 G11.1 G40.A19 G40.B19 324.1 G40.109 G43.109 G90.4 G15 G47.33 342.92 G40.901 G40.811 G93.89 G93.6 E75.23 G21.3 G94 342.01 G45 G37.0 G12.29 G47.61 334.8 343.2 349.9 342.80 G93.41 G25.83 G43.709 G43.819 335.9 G43.811 346.53 347.01 G47.8 G97.82 G34 342.81 342.91 G44.319 347.10 G43.611 G03.2 G31.9 G44.1 327.21 G23.0 G47.32 341.22 323.41 320.82 G40.B11 P91.9 337.9 G00 335.24 G47.411 321.4 348.31 346.91 327.27 330.2 348 327.00 348.81 G03.0 346 G44.041 321.3 G31.09 346.03 G28 G21.11 G25.2 G02 349.0 327.52 G40.A09 G40.821 349.89 G17 346.22 327.35 330.8 331.83 G81.13 G97.1 G23.9 329 G90.01 G40.911 333.81 G21.0’ P91.5 G43.809 335.19 G45.1 336.2 G24.02 335.21 346.92 G23.8 P91.4 341.0 G83.0 327.25 G47.25 346.52 G21.2 349.31 G25.9 G40.812 G24 337.21 331.4 G47.53 346.70 G91.2 345.11 330 327.09 344.03 G96.8 323.9 G44.019 G47.13 323.52 G44.301 324.0 G90.9 G42 346.73 320.9 G44.59 G25.82 G40.919 330.3 327.39 321.8 331.0 331.9 G30.0 G36.1 779.1 G81.03 334.3 G08 G47.21 331.3 G40 G11.3 G32 G04.39 342.10 G92 G36.0 323 G82.51 G45.3 G12.9 349.81 P91.819 321 G47.11 G40.A11 348.0 G93.81 G11 G40.801 G26 G80.9 342.00 G40.501 320 P91.3 G44.89 G90.519 G93.5 G81.91 G24.5 G45.8 331.19 323.61 G96.0 343.1

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Development	520.4 742.59 764.96 743.66 750.19 M26.36 756.11 749.01 748.1 524.33 740 740.1 752.35 741.0 743.53 524.79 748.5 752.42 589.0 Q18.1 Q26.2 Q93.4 764.98 743.43 744.21 Q63.8 753.23 750.4 P92 N13.70 746.82 747.40 743.57 743.41 742.5 752 743.34 749.14 524.35 744.82 Q05.2 M26.9 Q55.63 Q10.1 752.43 748.3 756.16 M26.89 743.31 593.71 M26.221 M26.72 313.23 Q31.1 743.49 F94.0 750.24 747.41 Q35.7 Q23.0 Q15.8 Q61.3 749.1 Q16.9 759.0 743.12 750.27 749.03 747.49 Q61.8 P92.4 743.65 750.21 Q20.0 Q87.81 Q62.4 758.5 764.03 524.73 Q17.1 756.13 524.31 Q34.8 Q18.4 Q27.8 520.8 743.64 Q21.2 741.9 751.61 Q76.5 524.27 Q05.7 Q61.01 746.87 Q10.0 Q25.4 Q36.9 764.06 752.36 743.11 764.91 Q28.3 747 756.14 743.39 759.89 746.6 753.12 750 750.10 Q62.31 M26.39 750.6 Q51.4 Q56.3 Q24.8 747.82 745.7 752.65 750.16 749.02 Q28.8 P05.14 743.35 Q20.9 Q64.9 P05.08 749.23 742.9 747.10 756.12 Q16.4 743.44 K00.4 P05.15 Q22.5 747.20 745.19 753.4 764.07 Q51.3 N28.83 M26.56 Q21.1 744.8 M26.220 747.8 N13.722 Q23.2 752.40 Q00.1 Q87.1 Q06.4 764.92 P05.06 524.56 743.46 Q55.22 745.11 744.0 Q51.2 K00.2 M26.52 Q76.49 752.89 Q52.12 746.0 Q99.2 E30.1 P92.2 M26.54 745.12 Q02 753.10 745.8 Q33.4 Q24.2 764.12 Q24.6 754.0 315.8 744.89 307.6 Q55.23 750.1 759.4 M26.73 Q00.2 Q40.8 752.64 M26.211 593.7 Q64.10 758.32 Q33.6 524.3 Q26.5 Q18.2 Q55.64 746.5 P05.9 764.00 744 752.34 752.9 Q43.4 524.57 Q38.2 759.1 747.2 315.9 Q13.4 759.3 524.22 Q16.2 315.4 743.63 752.51 Q27.9 745.3 524.32 743.54 Q20.1 F93.9 Q12.0 746.8 524.8 P05.18 748.61 P92.9 Q42.9 Q52.0 743.56 742.1 Q20.8 Q89.3 524.21 Q51.0 749.20 753.3 Q18.7 315 Q51.811 747.3 Q03.8 748.60 744.09 Q61.9 Q93.81 745.69 741.92 759.2 Q05.8 746.2 747.81 750.29 741.02 Q76.0 744.04 743.36 764.24 P92.8 P05.10 749.11 Q12.4 524.55 Q54.4 746.4 520.1 743.59 764.10 Q37.8 M26.33 313.2 P05.13 524.7 P92.01 745.61 752.11 P05.16 M26.34 Q24.3 751.5 524.74 Q06.2 746.00 752.10 Q50.6 Q21.9 752.49 745.4 758.31 752.33 K00.0 E30.0 753.15 307.7 758.1 746.1 Q04.8 764.13 M26.30 752.41 Q10.6 744.23 759.9 764.17 764.90 Q14.0 Q13.0 764.99 593.70 Q43.0 753.21 P05.07 744.05 745.6 Q98.4 744.47 Q52.9 750.3 743.45 Q33.9 764.97 753.7 741.93 764 Q23.1 Q30.0 747.1 752.6 Q15.0 593.73 741.91 M26.79 742.51 524.81 Q51.818 764.21 Q33.0 743.1 Q22.0 Q10.7 Q51.5 752.69 752.1 Q22.1 748.6 Q12.1 750.8 F93.8 Q36.0 745.0 751.8 752.4 Q34.9 747.83 747.21 754.1 746.84 753.5 520.9 524.30 747.60 747.61 R62.51 K00.9 743.52 742.2 Q12.9 753.0 Q51.6 743.9 743.5 759.7 Q89.7 744.03 743.03 753.22 Q38.0 Q38.3 759.81 M26.23 745.9 M26.24 744.02 524.82 P92.5 Q01.9 751.60 Q26.8 Q17.0 Q41.9 524.20 Q97.1 764.20 Q52.3 Q13.5 Q38.4 752.8 752.3 M26.4 746.3 M26.55 747.22 520 743.62 741.00 M26.57 749.04 744.9 Q17.8 756.2 758.4 Q45.1 M26.32 F98.0 P92.6 P05.12 Q17.2 524.26 524.50 748 P92.09 743.2 P05.05 741 756.4 Q10.3 N27.0 747.9 309.21 Q05.0 745 P92.3 Q14.1 742.3 Q62.39 752.47 Q51.810 Q17.3 740.2 Q14.2 Q11.1 589.1 746.09 Q45.9 743.10 747.89 K00.5 751.0 Q15.9 Q64.39 750.11 Q68.0 750.13 Q62.10 749.24 751.9 313.8 743.42 Q77.1 750.26 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758.81 750.0 Q64.4 Q96.9 742 746.85 743.30 313 743.06 Q14.8 R62.7 743.3 Q05.4 751.6 746.89 758.39 749.25 R62.52 752.19 N13.721 752.52 744.1 Q76.2 764.04 Q16.3 745.2 P05.04 748.9 764.14 764.94 520.7 749.21 753.19 750.7 Q25.0 764.27 F98.1 752.31 Q20.4 P05.03 Q91.7 759.83 746.81 743.48 749.0 Q50.01 524.9 Q40.1 745.10 524.76 P05.11 524.89 753.2 750.2 Q27.31 R62.59 744.41 744.46 751.1 740.0 Q67.4 749 K00.8 F82 Q64.79 Q23.4 764.93 Q27.0 753.11 Q11.0 M26.74 Q18.0 Q55.62 M26.37 Q21.3 Q22.9 Q25.1 524.4 745.60 750.12 752.32 742.53 Q37.9 Q44.2 524.71 R62.0 Q51.828 N27.9 753.6 743.8 593.72 524.54 744.00 524.25 750.9 Q61.5 Q30.8 Q23.3 751.2 524.28 746.86 756.10 524.52 M26.35 746.83 743.61 520.2 764.19 Q28.9 744.42 Q18.9 746.01 749.22 744.49 M26.81 743.37 751.7 747.29 P05.2 520.3 524.36 750.22 764.22 Q64.0 Q76.1 742.0 747.6 744.2 Q14.3 746.7 Q53.9 749.13 743.55 Q62.11 Q87.0 743.51 Q16.5 Q27.2 Q05.1 Q52.11 752.81 758.2 520.6 M26.31 524.39 Q18.3 Q93.89 M26.20 Q38.7 755.55 524.75 764.26 M26.53 744.4 758.7 756 524.23 R62 K00.7 Q40.0 Q05.6 524.2 Q13.81 K00.3 745.1 756.19 752.61 Q31.0 758 520.0 741.90 746.9 Q93.88 Q89.9 753.29 Q13.1 Q18.6 F81.9 746.02 743.00 Q44.1 743.47 747.69 Q39.1 Q38.8 753 764.23 764.18 753.20 Q27.32 764.09 Q17.9 Q23.8 Q89.1 Q13.89 M26.71 750.15 753.9 743.69 744.29 P05.00 Q40.2
Digestive	533.60 K63.81 531.30 K13 K42.1 K52.81 K11.4 K68.11 R15.2 K94.13 K42.9 K52.3 R10.811 R10.823 K26.2 578 K22.719 K64.9 532 K29.81 K76.2 K57.53 K59.02 532.50 K80.42 K57.80 K80.34 K08.123 534 K50.912 K56.601 K58 579.9 531.91 K76 K55.022 K55.30 K56.600 K08.133 K91.840 537.82 534.5 K08.51 K45 527 K80.30 K67 K63.3 K22.2 538 787.5 K26.5 K02 K66 564 K80.13 K22.6 R13.14 K51.211 K39 K05.00 K70.31 K00.4 K08.403 K13.29 K43.7 K70 541 R10.816 K09.0 K59.31 K85.82 532.11 K55.029 K00.2 K60.2 K92 K80.20 K08.122 579.1 532.91 K03.9 K76.5 R19.31 533.61 577.1 K50.919 K25.9 533.30 K35.2 534.2 K56.1 K63.89 K37 K57.40 533.91 K51.919 K05.212 K92.81 K13.79 R19.36 K62.1 K52.831 K51.40 531.0 K51.312 K50.812 K91.2 532.51 787.4 K40.40 K04.01 P77.3 K90.0 K22.3 K84 532.9 K64.4 K50.911 K69 K74.2 K92.9 K03 K64.1 R19.06 K08.119 K27.9 K57.30 K01 K08.414 K08.530 K21 K43.1 534.60 K08.0 K05.30 K80.44 562.12 K27.3 K56.699 K11.23 K50.118 R19.11 531.2 K13.1 K08.9 534.00 530.5 K11.9 527.8 K40.30 569.44 K62.3 K22.70 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K41.10 K08.531 K03.81 K75.3 K51.411 530.11 531.01 K22.9 K72 K64 K08.423 K28.5 K29.01 K08.21 534.40 K31.89 530.2 K27.5 K51.512 K29.41 K22.4 K27.1 K02.61 R10.821 K51.518 K85.10 537.89 K73 K27.2 K38 558 536 536.8 541.0 K94.03 K86.0 K57.13 533.4 K28.9 K38.1 K93 K51.011 R10.826 K50.818 456.1 K51.912 K08.20 568.82 K61.0 579.2 K14.9 K82.1 K06.8 K08.50 R19.6 K51.218 565.0 K52.89 R13.19 K51.911 568.81 P76.1 K57.11 558.41 K08.424 K55.021 R10.812 K91.72 K50.013 K70.9 K51.219 K59.09 K94.21 K05.312 531.60 K09.1 777.6 R15.0 K29.20 562.13 K91.83 K56.691 K05.11 K31.83 K60.0 K08.412 K55.032 K13.70 536.0 K08.101 K51.812 568.9 K44.0 K34 K55.039 R16 564.9 K65.0 K12 K04.02 K08.55 P78.1 K08.192 532.30 543 K71.0 K65.3 K08.59 K66.9 K35.89 560.3 K80.70 577.2 K31.84 K08.499 K41.21 P78.83 K14.6 K08.111 K41.00 K65.1 K86.8 568.0 K26 K51.311 K38.0 K76.81 787.91 K29.51 K07 K94.11 K38.9 578.9 K03.89 K55.049 543.9 K85.31 K52.82 R19.02 K08.82 566 R10.30 565.1 K14.0 K85.22 531.90 K29.90 527.4 K94.10 K80.80 527.6 K08.409 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Frailty		290 S88.911A F31.76 S98.919 333.82 897.3 F10.951 296.34 294.10 295.54 295.03 G24.02 295.53 295.33 298.2 295.52 296.32 S71.029A 295.70 331.7 891.2 S71.109A G24.01 296.21 295.80 F33.9 292.12 336.0 G24.3 G90.59 F19.94 S91.329 333.5 292.2 331.0 296.16 337.09 F28 296.81 295.34 F31.77 S81.829A 336.2 295.01 295.30 S98.912A 292.11 E75.23 291.3 F10.982 F44.89 S76.929A F10.159 G89.22 G32.0 292.89 296.25 331.89 F06.8 293.89 296.56 G90.09 296.22 334.2 F24 295.64 S88.912 333.81 G89.0 298.4 330.9 F31.63 G11.4 F06.4 295.91 333.3 G89.29 335.19 F23 295.24 F84.0 G31.81 F32.1 F31.30 295.84 G25.89 333.1 897.7 299.81 S98.019A 295.15 332.0 F29 F32.0 293.0 295.13 332 296.64 891.1 S98.019 335.21 F19.97 F30.3 335.23 297.3 333.6 338.28 299.10 F32.9 296.03 333.79 295 290.11 291.0 296.62 F10.239 S98.119 331 F30.2 R52 338.12 297 299.01 G12.9 S86.929A 295.23 S71.029 295.11 299.00 295.12 G10 290.13 337.9 G80.3 296.30 296.33 F33.2 F84.3 296 333.89 296.11 335.8 G25.0 F30.13 F31.73 F20.89 296.42 333 337 298 296.06 G31.09 G25.81 296.40 335.22 G90.529 F32.3 G12.8 F31.2 895 290.43 295.63 292 338.19 S71.129A 333.71 S91.129A 337.01 295.35 334.9 296.89 295.25 S88.119A S91.329A 290.9 331.5 F20.1 331.83 F20.0 293.81 G25.3 S76.929 295.94 295.85 290.41 337.29 291 G31.01 S98.912 298.1 S88.911 296.61 335.24 G32.81 G90.01 294.9 338.0 F04 G31.1 G25.82 291.4 892.0 295.73 334 895.0 F01.50 296.45 G20 290.42 891.0 G25.61 295.43 338.22 338 295.61 S81.009 338.11 S71.109 F84.9 F06.0 333.72 G25.83 F30.12 890.2 F31.32 G23.8 891 S78.119A G95.89 331.4 F31.62 296.53 F31.81 338.21 333.99 F10.27 295.02 G25.9 298.9 330 S78.119 F25.9 G21.11 S71.129 291.89 299 S91.129 294.11 296.63 296.7 296.12 295.41 F10.99 295.93 G89.4 F03.90 290.8 295.81 G90.9 295.60 295.40 F02.80 333.2 S98.119A G25.5 896.3 293.1 296.35 G89.21 F20.2 295.45 291.2 890 333.92 335.11 335.9 295.62 F31.60 F33.3 333.93 296.23 331.11 295.05 F01.51 F31.74 296.44 335.20 294 F05 897.2 337.20 296.52 296.10 296.51 333.85 295.44 G11.3 299.80 334.1 S98.911 291.81 295.75 291.1 295.71 296.04 293.84 296.13 296.41 337.00 G89.11 S71.009 S98.911A 331.2 897.0 299.91 291.5 893.1 F32.8 297.9 894.0 330.3 F32.4 G91.1 333.84 F32.5 295.82 S88.919A 296.26 330.8 F30.8 G95.0 331.81 S98.919A S91.309A 295.21 331.19 338.29 895.1 331.3 297.1 F10.929 338.3 G90.519 892 G24.1 G30.9 G95.9 G99.2 295.10 295.90 295.92 S88.919 295.83 292.83 F02.81 331.82 333.90 F31.31 292.82 G93.89 F15.920 296.15 335.10 G12.1 S88.119 F22 293.9 337.22 F06.30 336 299.90 330.1 296.43 F39 335 291.9 334.3 G11.0 892.1 897.1 897.5 893.0 295.95 297.8 F33.1 333.0 333.83 897 F84.8 G12.0 336.1 337.1 292.84 G31.89 F11.182 295.42 290.10 296.66 296.90 337.21 333.4 296.00 F19.921 G91.0 296.02 296.14 G91.2 F31.13 290.3 295.72 894.1 296.82 296.36 290.0 G31.83 897.6 F31.9 F34.8 295.14 G89.12 F30.10 F19.939 332.1 337.3 334.8 897.4 F32.2 896 G12.29 297.2 F31.78 G31.84 291.82 290.12 G12.21 295.55 296.24 293.83 334.4 G94 331.9 G24.5 F20.81 F31.61 334.0 296.20 G21.0' F19.950 S91.309 292.0 F06.1 294.8 G99.0 G89.18 F33.41 335.29 298.3 299.11 294.0 S81.009A S96.929 292.85 295.32 G31.9 890.1 298.8 338.4 S96.929A 896.2 896.1 298.0 F20.5 F33.42 296.65 S78.019A F31.75 893 297.0 S91.109 295.31 296.80 296.46 F19.951 892.2 333.91 296.05 F31.11 F31.5 F10.231 S88.912A F10.950 893.2 330.0 E75.4 296.55 F19.99 F10.96 295.20 G95.19 295.22 295.04 S71.009A 292.9 894.2 F31.64 890.0 G24.9 292.81 G93.9 295.50 S91.109A S81.829 296.60 G12.22 F19.96 S78.019 G11.1 F06.2 F30.11 896.0 296.54 296.50 335.0 295.51 290.21 290.20 G24.4 F20.9 336.3 894 338.18 F31.10 G90.4 G89.3 G89.28 293.82 293 F11.159 333.94 330.2 295.65 336.8 S86.929 290.40 F30.4 295.00 G24.8 F33.0 G93.7 F31.4 296.99 336.9 F31.12 295.74 296.01 296.31 G11.9
Health-Services		V58.49 V12.50 Z79.2 Z28.3 V04.5 V77.2 Z01.89 V06.3 V10.52 Z00.8 V12.49 V02.61 V70.8 Z93.52 V15.05 Z76.89 V03.89 V71.5 Z41.3 V03.2 V06.0 V02.60 V58.0 V15.1 Z22.31 Z11.59 V18.3 V15.02 V58.30 V72.9 Z82.49 V13.69 V53.7 V57.3 V03.6 V17.4 Z87.898 V12.01 V58.78 V77.0 Z02.1 Z71.3 Z48.01 V71.1 V06.1 Z22.51 V01.84 Z41.8 V54.19 V31.01 V64.2 Z38.1 S92.302 V64.00 Z51.11 V07.0 R13.10 V15.01 S59.101 V04.81 V59.9 Z09 V05.9 V01.79 Z02.81 V68.9 Z91.048 Z00.00 V80.2 V12.61 Z13.0 Z13.5 V67.59 V05.2 V09.0 V54.12 S92.302D V12.59 Z82.5 Z46.82 V54.89 Z91.012 Z11.8 V68.89 V17.49 V15.83 Z13.9 Z00.111 Z01.20 V02.2 Z72.820 Z22.50 V06.9 V76.3 V48.9 V72.7 V65.49 V67.4 V07.9 V74.8 V44.1 Z23 V54.09 V58.9 V55.4 Z91.011 V81.6 V77.99 V41.1 Z91.010 V61.29 Z91.038 V55.1 Z28.82 S72.471 S72.471D V29.3 Z87.19 Z48.812 V58.43 Z48.810 V70.2 V55.8 V81.5 Z76.2 Z48.813 Z47.89 V45.51 V41.0 V06.5 Z91.81 Z46.6 V13.02 Z97.3 V07.8 V71.2 V43.1 V75.7 Z13.220 Z01.110 V31.00 Z68.51 Z11.1 Z13.21 V58.74 V72.11 Z01.10 Z38.30 V82.5 V03.3 V41.6 Z45.2 Z11.6 V12.60 Z51.0 Z38.69 V13.7 V78.9 V71.7 V54.10 V54.9 Z11.2 Z55.9 Z39.1 V61.20 V44.52 V70.9 V33.01 V74.9 V05.8 V40.9 Z01.12 Z22.1 V75.9 Z53.29 V29.8 V49.75 Z43.1 S72.011 Z20.9 V54.01 S02.8xxD V20.31 Z13.4 V72.82 Z20.6 V20.32 F69 V12.09 V21.9 V05.4 Z96.1 V18.0 V30.00 Z86.79 V66.5 V04.82 V58.11 V67.9 V21.8 Z71.9 Z43.0 V62.3 V81.4 Z63.9 Z48.03 V67.2 V58.89 V15.09 V04.4 V78.3 V14.3 Z43.8 Z04.41 S42.101 V68.09 V53.6 V54.16 V20.1 Z98.89 Z16.11 V77.7 Z72.4 Z47.2 Z83.2 V03.81 V53.2 V15.86 V81.2 Z46.9 Z13.228 V85.52 V12.51 V77.6 V54.13 V03.5 V55.0 V07.1 V72.85 V54.15 V67.00 V72.1 Z00.3 Z86.718 V15.5 V61.8 Z85.830 Z86.59 V73.89 P00.2 V72.19 Z46.2 V09.1 Z20.811 Z79.01 Z04.9 Z51.89 V49.2 S52.90x V79.9 V71.81 Z85.528 V82.6 V01.7 V44.0 V19.6 V04.6 V06.2 Z38.31 V45.89 V72.84 V85.51 V77.3 V34.01 V65.43 V65.40 V69.1 Z22.330 H57.9 V04.0 Z77.9 V72.6 V07.39 V01.5 V71.9 V39.01 V12.6 V72.83 V58.82 V78.0 V78.8 V58.31 Z68.53 V44.2 V03.82 V85.54 Z76.1 V20.0 V58.69 Z13.89 Z01.810 V72.2 V70.0 Z48.00 V70.5 Z13.83 Z01.812 V45.2 Z88.3 V70.4 V06.4 V58.73 V05.1 V58.61 V72.31 Z52.9 Z00.110 Z87.01 Z03.89 Z83.3 V19.8 V15.89 Z87.440 V02.4 V49.5 Z86.69 V72.0 S59.101D V01.9 Z20.3 V10.81 Z13.29 Z01.00 V25.01 V13.9 S52.90xD V50.2 Z38.00 Z93.0 V78.1 V02.59 Z03.6 V72.69 V57.89 V02.9 V58.62 V67.51 V74.1 Z68.54 V79.3 Z79.891 V68.1 V07.2 V30.2 Z93.2 V58.32 Z08 V69.4 Z43.4 Z87.798 Z87.09 Z91.018 Z71.1 V04.8 V04.2 Z86.11 V77.1 V76.12 Z22.8 V15.88 V29.0 V61.9 Z12.31 V82.9 Z38.01 V03.1 V02.0 V54.11 Z62.1 Z01.411 Z63.8 Z48.89 S72.011D Z60.3 V16.3 V71.02 V71.89 V01.89 Z98.2 Z71.89 V14.1 V20.2 Z02.9 V58.81 V70.1 V18.19 V24.1 V65.5 V15.06 R68.89 V80.3 V79.8 Z51.81 V06.8 V72.5 Z89.519 V58.71 V30.01 V40.3 V71.4 V58.83 Z13.828 V19.1 Z12.6 V04.3 V19.2 V53.90 V29.9 V07.31 V12.00 V57.1 Z78.9 Z13.1 V77.91 Z68.52 V65.9 V72.62 V70.3 Z77.011 V14.0 V01.1 Z02.89 Z82.2 Z01.818 Z80.3 Z46.89 V05.3 V02.51 V72.63 Z04.71 V12.79 V17.5 V72.12 Z13.88 V05.0 V30.1 Z86.19 Z00.2 V15.03 V53.09 V72.60 Z76.0 Z30.011 V04.89 V03.9 Z04.3 V85.53 P00.9 V21.0 Z20.1 V58.3 Z84.89 Z93.1 V49.89 Z88.1 V40.1 V62.4 V21.2 V82.3 Z02.79 V72.81 S42.101D S02.8xx V41.2 Z48.02 V39.00 V67.09 V65.8 V65.3 Z20.89 Z22.0 Z11.9 Z04.6 Z46.1 Z00.129 Z16.10 Z83.49 V50.3 Z28.9 Z88.0 V71.09 Z13.6 P00.89 Z97.5 V02.1 V82.89 Z01.811 V57.21 V06.6 Z41.2 V64.05
Hematologic		D68.59 P59.29 D72.822 P58.42 P52.5 D50.0 P61.2 280.8 P57.0 P50.8 P52.0 282.69 286.0 774.5 D69.2 P50.0 P10.0 281.8 D57.411 D51.0 287.8 286.7 282.5 287.32 774.1 289.51 D55.9 P59 772.14 282.60 280.9 D53.8 D57.211 D59.9 284.8 D61.811 D59.2 D59.6 282.1 D73.81 P52 D61.09 287.3 281.0 282.42 773.4 P50.1 283.11 287.5 286.1 D68.318 D64 773.5 D68.8 285.21 776.4 772.3 D72.820 284.1 P51.8 D63.0 283 P61.5 D78.02 D59.1 772.9 P59.9 283.10 D50.9 D59 D68.311 D53 P10.8 D78.34 D75.81 D72.9 D57 P10 287.39 776.3 D58.9 P10.1 286.4 D74.0 287.31 D55.8 D75.0 285.29 D68.61 D78.81 D72.810 D69.9 D55.2 D60.0 D52 P55.0 D73.0 282.61 D59.5 P54.6 D53.0 285.1 285.22 289 D64.1 289.82 D59.0 D78.33 P61.0 D63 284.0 D61.1 D74.8 P54.2 289.81 281.9 D64.2 D76.3 776.7 P58.0 P58 D57.412 P58.41 773.0 772.13 D64.3 D61.9 D53.1 D68.52 D72.828 D75 P60 P52.8 D52.1 D60 P58.8 283.1 P57 D70.0 D78 D58.1 D69.49 289.59 P61.1 281.3 282.49 D68.32 283.9 D58.0 286.5 P52.4 D69.3 D73.9 D68.51 D57.80 774.31 D57.819 286.3 D78.21 284.81 D73.1 D77 282.68 P10.3 D56.4 D68.0 D73.89 D78.12 D58 284.2 D55 D76.2 P61.8 776.6 282.7 776.1 D53.9 289.52 D57.811 D56.2 D75.9 284.9 P52.6 287.30 D72.829 D68 772.6 287.0 D52.8 282.62 D68.69 776.0 774.4 D72.825 286.2 D57.812 P54.4 284.09 P61 D72.819 284.89 D73.2 282.40 D57.20 284.01 D68.2 D72.0 P58.9 D75.89 D55.3 D61.82 D56 P54.1 773 D53.2 282.9 D56.8 776.9 D69.41 772.4 P56.0 D60.9 D78.11 P59.0 286.9 D78.32 281.1 285.8 D52.9 P50.3 287.41 D57.212 289.8 287.33 D72.823 D72.824 282.64 P54.3 P55.9 D59.3 D58.2 D60.8 D70.4 D51.9 D69.42 P59.8 P61.4 D64.4 D69.1 P57.8 D75.82 D69.6 287.1 P58.2 280.0 P58.5 P56.99 P61.6 772 P50.2 D56.1 P50.4 D70.3 P52.21 284.19 D78.01 282.2 D70.8 D51.1 D50.8 D61.818 D51.8 D57.02 D57.1 D75.1 287.2 774.0 P51.9 774 D69.51 P54.8 P58.1 282.41 285.2 D56.3 P54 D72.818 287.9 P55 P61.9 P55.8 772.8 D54 D52.0 773.3 282.6 D73 D61.2 772.0 774.2 284.12 D78.22 282.8 287.4 D64.9 D55.1 P59.3 P52.22 D74 P54.0 D70 280.1 287.49 287 D76.1 D78.89 289.7 P52.1 D72 D50.1 289.89 D72.1 P56.90 281.2 772.2 286.6 772.11 289.4 D68.1 D59.4 D69.0 D73.4 D58.8 P52.9 D67 P59.1 776.8 D59.8 289.9 283.19 284.11 D61.3 D51.3 D61.89 D66 D57.40 283.0 D71 D56.0 281.4 D61.01 772.10 D69 284 P56 772.12 D51 774.6 D56.5 285 P10.4 D78.31 D63.1 D70.9 P54.5 D72.821 D57.219 P59.20 D57.3 D51.2 D64.89 P61.3 P50.9 772.5 D69.59 285.3 P54.9 D68.4 P55.1 285.9 776.2 289.50 D73.5 282.3 D62 282 776.5 D72.89 282.63 P57.9 D61 D57.00 D63.8 P51.0 D70.2 D74.9 P58.3 P52.3 D56.9 D55.0 D57.419 776 D68.62 D69.8 D68.312 D70.1 289.83 774.7 D64.81 773.2 774.39 D64.0 P50.5 P50 P53 D61.810 774.30 D76 P51 289.5 D73.3 773.1 D60.1 D68.9 P10.9 D65 P10.2 D50 D57.01
Hypertension		404.00 403.00 I15.9 403.11 404.0 402.00 404.10 I11.9 401. 403.0 I13.10 403.90 405.9 I16.1 402.10 402.1 404. 403.1 I15.2 404.11 404.03 403.9 404.1 405.09 404.91 I15.0 401.1 405.0 405.91 403.10 404.12 40311 404.9 404.13 I13.11 I12 I16.0 403 401 402.91 404.02 405.1 I10 I15.1 402.0 I15.8 405.99 405 I13.0 402. I12.9 402.01 I16 403. 404.93 401.9 I11 404 405.19 I12.0 404.01 403.01 403.91 405.01 405. 402 I15 I13 404.90 I14 402.90 404.92 402.9 402.11 I16.9 I13.2 404.04 405.11 401.0 I11.0

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Immune		H10.439 716.08 M86.642 273 003.23 M46.80 288.65 711.03 360.04 716.86 I89.9 I80.3 279.00 477.9 M02.369 K52.81 N34.0 711.11 582.81 728.82 K29.81 I89.0 715.15 597 710.0 A39.83 730.25 716.46 E10.11 M02.169 D73.81 M15.9 M81.0 J34.81 716.10 708.8 J32.9 M16.10 451.8 511.0 G37.9 M12.129 711.64 716.15 E06.0 H01.019 478.22 254.9 716.8 535.2 595.2 730.13 J45.991 692.84 J32.0 711.05 446.0 721.42 D89.0 M86.179 373.32 G35 D84.1 I05.8 555.9 571.49 716.43 250.23 D80.3 250.83 249.61 N03.5 250.21 535.10 459.10 H57.13 719.33 H16.309 733.01 476 451.84 249.20 711.90 464.2 D86.1 M12.829 M33.90 D89.49 288.0 J35.03 493.81 J35.01 250.81 715.10 713.2 475.0 711.83 721.4 K51.40 711.86 M94.0 716.35 716.02 716.88 254.0 L41.8 289.3 364.0 D72.828 M12.00 535.71 711.58 M13.80 716.01 M05.60 692.3 H57.8 M02.339 H15.129 716.20 711.84 288.6 N30.30 M02.319 363.05 711.65 376.12 M86.149 373.31 716.6 396.1 M08.3 E32.1 H30.009 696.8 D86.82 D83.2 535.21 713.6 370.60 478.24 M12.80 695.15 363.12 582.9 M02.149 373.2 373.1 245.0 474.8 715.93 H30.029 I08.0 M13.849 E10.21 530.19 D81.0 464.10 L50.8 L24.0 M02.10 376.1 716.41 249.00 478.20 E32.8 I02.0 476.0 M12.529 711.95 464.20 N30.20 279.8 729.4 L40.8 716.38 D81.819 D84.9 E31.0 M12.9 715.95 M86.9 370.61 D72.819 692.6 363.22 M02.359 M13.829 372.10 686.0 360.1 396.0 249.5 535.4 711 D83.0 M01.X49 716.29 714.81 I77.6 H01.129 716.85 D86 E08.21 535.51 693.0 H30.129 397 711.21 D80.9 595.1 D72.824 446.3 364.11 242.01 M46.90 M13.149 730.01 M12.379 474.11 373 D81.818 I01.9 716.42 478.21 279.11 J34.1 L28.2 370.55 730.28 556.5 E08.40 711.52 373.3 595.3 249.90 582.1 730.07 I80.219 711.63 289.1 D80.5 M12.519 D81.2 288.02 K51.80 556.8 394.9 446 J37.1 288.66 364.00 715.30 D80.7 J44.0 711.76 730.06 M72.2 D89.811 D89.9 696.4 I87.009 M36.2 711.09 398.99 E10.65 595.81 446.29 716.91 711.91 711.18 E10.9 M12.579 715.04 H15.019 288.01 555.1 I87.099 694.6 M34.1 711.44 519.2 K58.9 477.8 364.1 D86.2 250.71 715.24 E08.65 711.24 M05.10 715.16 714.2 714.0 715.17 394 711.50 L20.89 716.84 464.21 M31.30 M86.18 464.01 716.49 G37.0 446.7 711.53 711.47 L27.0 M06.4 461.0 M12.88 J04.10 695.4 M12.19 H01.029 J04.11 372.31 H16.249 363.04 459.19 457.8 478.11 714.31 711.9 E09.65 M02.159 D86.89 493.11 M60.20 711.73 H00.039 J35.1 J45.990 716.60 730.20 711.60 D85 H16.429 457.9 L73.2 459.13 716.12 696.3 K29.01 M02.179 474 370 555.0 M31.0 711.43 363.14 711.08 H20.9 K29.41 245.4 H05.10 M33.20 363.03 379.01 716.54 250.41 373.34 L92.3 363.20 716.50 464.11 716.63 446.4 I73.1 694.60 511.89 715.98 249.31 461.9 L51.1 715.34 I06.0 M02.349 711.35 395 711.88 474.9 716.61 I06.1 711.15 D86.0 370.9 711.82 M13.139 D89.89 716.34 372.12 H40.40x0 M13.0 I07.2 I80.8 711.12 715.9 L04.9 716.44 730.00 730.21 J01.20 711.33 H30.139 692 D86.84 M02.18 535.50 M00.09 H20.819 708.1 M19.079 M12.319 716.51 556.2 M13.159 L10.9 288.04 289.6 M35.00 279.09 730.0 E08.10 695.12 363.07 459.1 370.63 716.87 692.9 L30.4 364.04 M13.869 451.89 715.21 392.0 M12.119 720.89 249.4 686.09 711.20 H30.93 711.40 715.26 K52.2 L21.9 716.95 D89.2 D80.2 J91.8 379.93 M12.339 J30.5 693.8 715.80 M17.5 D83.1 720.0 249.71 461.2 571.40 711.5 L92.9 D81.7 358.0 H20.13 730.24 249.60 396.8 711.81 M01.X8 580.4 695.11 363.1 716.96 715.97 250.53 E08.620 475 716.53 249.70 M08.40 J35.9 D80.4 D70.4 478.29 715.27 M02.129 G70.00 H16.269 451 M00.08 373.9 L08.89 693.9 710.1 686.01 K29.90 H10.409 M30.0 451.19 396.2 363.00 530.10 M12.169 M47.10 M14.80 714.3 493.1 E10.39 716.99 M13.88 M02.00 E05.01 477 K29.00 E09.311 N03.8 E04.1 698.2 H16.449 728.71 J30.0 D80.6 464.0 711.29 461 288.3 571.41 L44.8 721.41 719.36 597.89 474.00 N00.9 711.98 I08.8 711.89 M12.50 D72.825 713.0 564.1 721.91 711.87 711.80 H20.829 N08 H44.019 716.22 341.1 I06.2 715.36 443.1 E10.29 D72.0 279.05 715.13 J01.40 457.0 373.00 711.45 579 M47.16 I01.8 H20.23 277.39 M01.X39 716.65 L93.0 289.2 461.1 535.41 279.2 M19.229 M17.10 I88.0 E10.51 H40.40x 730.26 J01.90 M00.019 M19.219 715.18 D70.4 716.11 708.0 695.89 711.28 250.43 M86.669 716.16 M12.18 K75.4 M02.379 L53.0 711.31 249.7 H30.039 H10.429 288.61 394.1 D86.9 H20.049 556.9 694.8 D70.3 D70.8 L50.3 M02.39 730.04 451.0 D87 325 288.60 473.9 M02.19 I09.89 694 E10.40 D84.0 698.4 E06.9 H05.119 250.31 L25.9 M00.049 711.69 692.8 L52 245.3 706.3 711.32 K51.50 E06.4 720 M08.00 711.94 396 K29.80 M86.659 716.06 D76.1 D82.9 711.49 279.03 580.81 715.06 397.9 535.61 535.00 715.08 L25.1 M31.4 715.90 288.51 358.00 K51.90 716.93 J45.909 D82.1 716.55 370.6 H01.9 J39.2 713.1 I80.00 M12.369 360.00 J04.0 D84 696.0 730.23 250.03 H15.059 373.12 K29.91 288.2 M86.68 D70.9 J32.1 715.35 I88.9 250.61 473.3 379.06 711.54 715 M19.249 M12.39 I80.10 692.1 730.08 394.2 716.48 M47.14 364.23 K51.00 711.48 716.17 373.11 719.30 370.62 M19.279 446.20 535.5 099.3 716.9 711.68 M30.3 372.1 711.72 716.07 379.0 J35.2 249.6 715.23 716 364.22 H01.009 719.3 716.89 716.81 711.70 730.14 720.2 708.9 582.0 N30.10 715.89 556.4 580.89 398.90 N03.3 716.21 711.14 398.9 L51.3 D89.82 H44.029 398 E05.00 716.67 719.37 451.83 711.42 710.3 D86.83 363.2 396.3 H16.339 360.01 711.7 249.9 370.54 I39 493.8 711.6 582.4 H15.009 715.31 245 714.8 249.30 E32.0 451.2 D83.8 535.70 D81.1 I87.029 E08.9 245.8 511.8 714.4 719.39 696.1 279.12 711.37 711.16 715.2 M19.039 M16.7 597.0 M46.1 L23.0 372.13 457.2 M15.0 711.06 692.4 H16.409 370.50 715.25 J45.21 I80.209 I88.1 713.7 713 708.2 555.2 M31.1 395.2 462 M12.869 242.00 J01.10 H01.8 288.64 K29.61 373.01 379.00 730.27 E08.51 M00.069 L51.9 711.2 288.5 473 379.04 493.0 715.09 714.32 E32.9 457 J94.1 721.1 249 535 493.91 L30.5 D86.85 E08.8 373.33 J05.0 373.0 716.40 D81.5 493.12 715.96 692.81 K50.80 493.00 D81.4 J30.2 H01.119 K73.8 M19.029 279.3 J02.9 595 N03.9 I08.9 L50.1 H00.019 J30.1 695.13 L50.5 716.27 M16.9 711.17 730.19 H20.019 364.10 L98.1 595.0 L44.0 L30.1 530.12 716.0 288.69 730.22 E06.1 556.0 715.22 360.03 A02.23 683 364.24 730.18 279.02 451.81 H44.009 716.09 J39.8 N30.81 D89.3 254.1 373.13 730.09 K52.1 720.81 364.02 M14.60 288.62 464 M12.149 716.30 M19.049 I80.9 391.8 715.33 L00 711.36 571.42 358.01 511.9 364.21 711.56 279.13 711.71 446.5 D83.9 711.66 M00.029 711.02 D72.829 370.52 711.78 L88 363.11 719.31 M00.079 360.02 695.1 249.21 D81.89 711.13 M12.859 715.05 D80.0 571.4 M12.179 D88 M15.1 M13.10 N00.3 M19.90 713.3 H30.119 372.14 K20.8 735.2 705.81 D81.6 H16.439 J35.8 464.00 M35.3 711.39 L27.2 N03.2 M12.30 D72.823 719.32 478 363.21 250.73 J01.30 250.01 M31.6 245.1 478.8 692.0 694.9 G70.01 693.1 493.82 D81.810 L27.9 715.91 714.9 M13.819 M12.329 J32.4 477.0 597.8 I05.1 478.19 I97.2 714.89 E08.01 363.13 711.0 493 720.8 364.05 474.01 M01.X69 691.8 288.50 493.01 289.53 459.12 H16.329 249.91 H30.23 D82.2 716.90 535.40 I89.1
Infections-Bacterial		041.4 T79.A21 T79.A29 041.86 A43.0 034.1 020.1 030.0 041.5 A27.89 038.2 023.3 T50.A25D A25 021 A24 040.89 A48.0 036.1 041.7 040.82 041.10 039.3 T50.A24S A39.83 T79.A22A 036.3 A23.9 B96.81 A44 041.04 A48.51 026.1 A37.80 032.84 041.00 A41.02 H90.A21 A22.0 A40.0 B95.0 A27 A21.2 A49.3 T50.A22 T79.A29S A48 020.3 040.3 041.84 038 A30.3 020.5 T50.A22D I82.A23 H90.A32 A39.50 T50.A21A J02.0 A22.8 A36.2 T50.A23A A41.89 038.19 041.3 A41.81 A20 A30.9 020 A22.2 A41.2 A32.89 041.03 030.8 A23.0 036.81 A28.2 A36.85 A39.9 032.2 041.6 A49.8 I82.A29 036.42 B47.9 M79.A21 T50.A25A 020.8 M79.A22 038.40 041.83 A31 038.44 T79.A22S 040.81 027.2 027 032.83 A46 038.49 039 041.85 036.40 A44.0 T50.A22A 038.42 A42.89 B95.7 A21.8 A41.01 A36.9 A39.3 A20.9 A40 H90.A22 T50.A26A A49.01 A37 023.1 041.09 A49.9 A49.1 A22 A23.1 T79.A21A A48.52 A49.2 A22.7 A42.7 A28.1 M79.A29 034 A32 031.0 038.10 A38.9 A21.9 037 A21.3 A48.3 038.0 A48.8 A39.1 022.0 A49 020.9 A28.9 A39.89 026.0 036.0 036.82 A30 T50.A26 A44.1 041 T79.A21S 036 A26.7 A28.8 039.1 A22.1 022 B95.1 A41.1 A36.0 A44.9 038.3 020.0 A27.0 038.12 A20.0 A43.8 023.9 A23.8 A39.53 027.9 B96.4 T50.A23 A41.9 A36.3 033.1 030.9 040.2 A25.0 A41.51 A32.12 A36.86 A23.2 A39 022.8 029 B96.89 A22.9 030.1 034.0 036.43 B95.8 A38.0 T50.A24 B95.4 B96.5 T50.A26D 027.8 A40.8 T79.A29D A36.1 A39.82 A43 A44.8 040 039.2 T79.A22 021.9 A43.9 L08.1 A26.0 020.2 A37.10 036.41 022.1 041.9 A42.82 038.41 A41.50 A35 B96.7 021.1 T50.A21S A49.02 T50.A21D A32.7 T50.A23S A20.1 T79.A21D A37.11 A48.4 T50.A25 A36.81 A41.53 033.8 A30.8 032.82 A21.1 A36.83 032.81 A21.0 A39.2 A32.11 023.0 A40.9 041.19 M60.009 021.2 032.1 035 A40.3 B96.1 028 A36.82 022.3 A34 A37.01 036.2 A47 023 B95.2 A38 A30.1 033.9 A42.2 041.81 032.89 A30.4 A39.4 A39.0 I82.A22 020.4 A41.4 027.0 038.8 A39.52 021.3 036.89 T79.A22D A21.7 A32.9 031.2 A37.81 041.89 A37.91 T50.A23D A30.2 A23.3 T79.A29A A42.9 030.3 A32.82 A40.1 A32.81 A26.8 T50.A26S 038.43 B96.3 H90.A31 A31.8 039.4 041.01 032.9 039.9 024 040.42 040.41 030 A39.51 041.82 041.2 A36 030.2 A41.59 A48.1 A26 T50.A25S A38.1 025 021.8 A31.1 A37.00 040.0 026.9 031.9 027.1 036.9 A42.0 032 031.1 023.8 A24.0 A28.0 A43.1 B95.61 B95.62 A20.3 041.11 A31.0 I82.A21 A25.9 022.9 A42 A41.3 B96.6 B95.3 A30.0 041.12 038.9 A45 A28 A30.5 A48.2 031.8 A20.8 A31.9 A39.81 T50.A24A 040.1 A31.2 A39.84 A25.1 A42.81 033 T50.A24D A24.1 A27.9 A26.9 A27.81 B95.5 A23 K90.81 021.0 041.05 A37.90 032.3 039.0 A36.84 A42.1 033.0 A33 032.0 026 A32.0 A29 T50.A22S 023.2 032.85 A24.9 A21 A41 T50.A21 039.8 A24.2 038.11 A20.2 A24.3 A20.7 041.02 A41.52 022.2 A36.89 A38.8 031
Infections-Fungal-and-Other		B46.4 122 B90.2 M86.642 B76.8 B58.81 M90.829 123.0 B87.2 B77 T50.B96D B69 136.4 B63 B37.1 B54 117.4 122.3 M62.3 B40.81 B67 B47.1 126.2 B60.11 B94.2 M62.89 122.4 B95 114.4 B35.0 133.8 138 123.1 115.00 B73.1 B74.8 B81.2 128.8 728.82 B57.1 728.3 B57.49 B48.8 B60.12 B35.2 139.0 116.2 B65.8 B37.81 730.91 T50.B93S 117.7 B65.3 B39.5 B94.0 B88.2 M90.869 B67.39 115.94 730.00 127.3 730.21 B75 728.85 B51.0 125.2 730.25 B37.3 B96.81 B40.89 134.9 133.9 M90.839 131.01 131 B43.1 B83.9 B57.32 B65.0 136.29 B36 B37 122.2 B87.89 B95.0 B50.0 B66.8 114.9 B66.2 730.81 B43 B44.89 M90.849 115.10 B38.89 B40.9 M62.838 B71.1 B83.2 130.1 730.94 B42.89 112 B60.0 B35.5 B74.4 B38.7 B52.9 M86.639 B98 117.8 B97.32 137.2 B42 B97.11 127.9 B50 730.27 B37.6 122.5 B58.9 B81.3 115.03 I32 B39.1 B37.41 122.6 B58.89 730.98 B56.1 115.99 B46.9 730.13 112.9 B55.9 T50.B96 730.95 B59 A07.8 T50.B91 T50.B92D B46.0 B67.4 M46.30 123.6 B76 B77.0 112.89 B37.84 M86.179 136.5 115.14 B73.00 B47.9 B36.0 B60.10 B45.2 730.77 730.36 111.0 B38.2 B80 120 730.38 B40.3 B48.3 130.9 B40.2 121.5 B37.0 730.82 730.32 B83.1 112.1 122.8 M89.659 M62.81 110.4 T50.B94 B53 B43.0 730.03 117.5 111.3 B81.1 T50.B91D B46 M86.619 728.10 127.8 128.9 B88.8 130.2 M86.19 730.29 137.3 136.3 730.24 B97.0 113 B57 136.9 B87 B95.7 728.81 B97.89 B45.8 B45.9 110.6 121.2 B76.1 M46.20 B37.9 B97.10 B74.3 B57.0 A59.00 B66.1 B77.89 112.5 730.19 115.13 B37.83 111.1 728.0 B55.1 B35.1 B78.9 117.0 730.22 B85.2 H32 M86.60 M62.00 M86.20 730.17 112.84 730.18 B38.0 B71.9 728.12 B53.8 B79 B60.2 M89.619 T50.B93 B97.35 M86.149 B45.1 B37.5 A59.9 730.09 B38.1 B67.7 126.3 M90.879 728.6 B51.9 111.8 B35.6 123.4 M61.10 B78.0 121.1 B58 B44.0 B40.0 B72 B97.4 B35.4 730.76 730.15 730.39 T50.B95A B37.7 112.83 730.75 B96.22 117.2 M89.669 B36.8 728.71 B41.7 B71.0 B71.8 A59.8 B48.0 110.9 B56.9 B65.9 M35.7 B67.99 127.7 730.96 B44.9 T50.B95D M62.82 B65.1 B88.3 L94.6 730.88 123 B68.1 B46.2 M60.10 B68.9 B95.1 B86 B43.2 T50.B96S B87.81 112.81 114.0 728.2 B60.19 131.9 B57.42 120.9 131.8 B97.39 B83 M89.679 137.4 125 130.4 730.33 B96.4 117.1 B78.1 B99 B97.5 133.0 133 130.0 121.4 B88 T50.B92S 116 B57.2 B37.2 A59.03 123.5 B85.1 B78 B41.8 M86.9 B38 112.2 139.1 B97.29 B96.89 B51 123.9 B38.4 129 B40.1 B97.12 123.2 B40.7 728.5 B99.9 B88.9 M61.40 B71 B81 114 730.31 J17 121 B36.2 B50.8 B95.8 B81.0 132.9 B57.39 M72.4 T50.B91A B55.2 B69.81 134.1 132.0 B39.2 T50.B93D 110 B42.1 134.8 B77.81 126.0 B67.5 B95.4 T50.B91S B41.9 B96.5 B48.4 B69.89 B67.61 132.2 B46.5 M24.20 B85 B35 115.04 T50.B92A 123.3 B58.00 B37.42 B47 115.05 B68.0 110.0 B36.3 B85.0 B87.9 115.01 730.26 126.8 110.5 T50.B95S 121.6 730.30 730.01 B56.0 130.8 B60 B87.82 B83.4 728.19 730 B51.8 728.11 B67.69 111 B90.9 B94.1 B96.7 M86.669 B52.8 B96.21 728.89 730.12 B38.81 B45 B73.02 B67.8 B58.2 124 730.28 B67.32 121.0 110.8 B87.3 134 D86.9 132.1 A59.09 M90.819 111.2 730.07 B66.4 115 125.7 130.3 B39.9 B85.3 B67.2 728.84 730.04 B69.1 A59.01 134.0 B38.9 B40 B94.9 115.12 B55.0 B42.7 127 B36.1 B97.33 B93 136.8 M60.009 128.1 B74.2 B96.23 121.8 B85.4 M90.80 A59.02 730.10 112.4 B39.3 117.9 B96.1 730.06 M72.2 B73 B82.9 B66.5 B69.0 139.8 B95.2 137.1 B42.0 B46.3 B48.1 115.09 B67.90 B94.8 137.0 M86.169 130.5 M86.139 131.09 115.02 T50.B93A M61.00 125.1 120.1 128.0 139 M89.69 728.87 M86.659 730.16 132 B78.7 B35.3 M86.129 116.1 120.0 B44.1 122.0 B39.0 B45.3 730.37 730.72 B57.40 730.85 B97.21 B82 B74.0 M86.119 128 M86.69 B39 B94 136.21 B58.83 728.88 B57.5 B39.4 T50.B94A T50.B92 B38.3 120.8 B99.8 M86.159 B96.82 730.78 B74 728.13 B48 730.80 B82.0 B36.9 B46.1 T50.B94D B68 B37.82 B96.3 B43.9 728 B58.3 122.9 728.79 T50.B96A 730.35 730.11 B62 B90 B97.81 115.91 M89.629 B81.8 115.19 B96.20 B42.81 B90.8 B97.6 B84 M72.0 132.3 126 B97.34 B41 B65.2 127.4 B45.7 730.02 M90.859 125.0 114.5 111.9 730.89 117.3 730.83 M86.18 B49 B70.0 730.90 M62.9 110.3 115.90 T50.B95 B66.0 110.1 B88.1 131.02 M72.6 B57.30 126.9 730.87 730.23 135 M62.50 110.2 B44.7 134.2 M61.9 117 B44.81 B95.61 B95.62 B69.9 B52 M86.68 B65 114.3 T50.B94S B97.31 125.5 B76.9 B45.0 M35.2 B70 B74.9 M61.59 B77.9 M89.60 B70.1 730.34 116.0 125.6 127.2 B67.1 728.9 B81.4 B90.0 730.08 M89.639 B50.9 119 B60.8 B43.8 B52.0 B96.6 B97.30 B66 B89 B87.4 B95.3 120.2 M62.10 B97.19 728.86 B37.89 B57.41 B58.09 136.0 122.7 130 136 127.1 B90.1 730.71 G02 B92 114.2 B87.0 M60.20 730.84 730.86 730.99 112.85 B64 114.1 730.92 B61 730.20 M89.649 125.9 115.93 B42.82 B73.01 127.0 136.1 117.6 730.05 730.73 115.11 121.3 B57.31 M86.679 B97.7 B35.8 M86.629 730.14 B76.0 B87.1 B83.0 B73.09 B96.29 M90.89 127.5 B83.8 B60.13 121.9 123.8 B95.5 B44 B53.0 126.1 B58.1 112.3 B41.0 B97 730.74 728.83 B46.8 B47.0 B37.49 125.3 B91 B96.0 130.7 131.00 B58.01 B74.1 B56 B53.1 730.70 127.6 B83.3 B66.3 B67.0 B66.9 I39 112.0 120.3 B44.2 B55 B58.82 730.79 B42.9 730.93 B48.2 728.4 115.15 131.03 122.1 730.97 112.82 137 118 115.92 125.4 B67.31 B88.0 M89.68 B35.9 B96 M90.88 115.95

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Infections-General	041.4 017.10 B02.21 055 098.14 042.9 B09 011.80 569.5 B69 136.4 A19 078.0 057.8 A50.09 017.81 590.3 083.8 016.4 013.83 003.8 B67 341.21 372.05 016.32 380.12 015.62 017.20 466.1 380.2 001.1 001 A52.10 B94.2 H70.009 B35.0 A92.8 017.44 017.82 123.1 115.00 016.71 B74.8 T79.A12S 081 016.60 011.8 B02.24 T50.A15A A05 B60.12 T50.A25D A04.9 B33.23 T50.A11A 682.6 098.41 B35.2 116.2 N37 018.92 040.89 A77.0 117.7 095.8 045.1 A07.4 A63 B08.1 018.01 070.3 B88.2 M90.869 482.42 A85.1 005.9 041.10 015.5 375.30 A39.83 016.36 013.53 B96.81 011.93 488.11 041.04 A48.51 B26.1 A73 A08.32 B43.1 A18.4 B65.0 A41.02 T80.A19D 018.85 B16.9 066 B87.89 060.1 I82.B29 324.9 P36.2 012.85 685 B50.0 A27 A66.5 070.70 A66.1 B02.9 T50.A93A P35.1 A48 100 B17.9 590.1 058.1 079.3 130.1 B06.00 B42.89 112 017.9 B60.0 T50.A22D B74.4 B52.9 046.2 077.9 381.1 086.0 483 056.01 A54.41 016.24 062.4 A83.9 K67 B97.11 449 085.0 007.8 013.62 A92.9 P36.39 T50.A94S 016.1 011.5 J05.10 466.0 A50.07 B00.82 015.61 B81.3 017.76 012.81 B08.010 015.04 771.3 A30.9 063.8 016.93 A52.05 B02.0 A22.2 059.22 041.03 008.69 011.23 381.0 A06.9 380.1 083.1 A28.2 A36.85 B46.0 013.14 070.52 B77.0 082.40 054.1 482.89 112.89 A02.0 T50.B12S 010.02 032.2 A18.54 B27.82 B73.00 008.5 047 036.42 T80.A10D M79.A21 B45.2 A08.39 681.0 111.0 T50.A25A B40.3 B48.3 375.31 094.1 017.33 014 J31.0 038.4 G00.3 B83.1 045.23 011.43 045.01 T50.B94 041.83 071 015.21 B43.0 016.53 048 094.8 472.1 016.04 010.94 073.7 A96.9 017.4 079.52 015.12 127.8 016.14 T80.A11S A00.1 097.9 A07 011.64 A66.3 038.49 039 100.81 137.3 136.3 382.2 B57 006.0 038.42 A51.45 B87 B95.7 771.1 H70.209 483.8 012.1 A36.9 010.01 063.9 J15.20 B97.89 420.91 B26.85 B45.8 081.2 074.22 A88.0 014.06 042.0 567.3 115.13 B55.1 016.54 016.35 B35.1 573.3 053.13 A37 015.75 079.2 J18.9 N11.8 008.45 056 A52.06 A54.83 A23.1 093.81 A53.0 424.90 A54.84 I40.0 H10.239 A48.52 A49.2 112.84 013.23 016.41 099.55 051.0 004.9 093.20 B14 B24 373.4 011.72 B79 098.39 M89.619 T50.B93 A80.9 091.1 A32 A17.82 031.0 M90.879 043.1 488.1 A51.9 J09.X3 A87.2 123.4 G00.9 A21.3 B40.0 B97.4 066.49 A02.24 038.0 B06.01 A48.8 017.06 730.76 421.1 098.5 094.83 020.9 001.9 115.9 015.66 A02.22 A50.03 B37.7 026.0 077.98 482.8 730.75 117.2 055.0 A93 A77.8 A04.5 A01.05 B02.32 003.21 A53.9 322.1 B48.0 B56.9 A44.1 098.50 015.70 B17.2 B67.99 H60.399 098.59 T50.A94 T50.B95D G03.9 A01.2 123 039.1 077.4 682.2 P35.2 T50.B15D B31 017.66 A80.39 A81.09 381.3 B87.81 B60.19 B32 038.12 074 321.2 131.9 012.8 A43.8 B57.42 131.8 015.92 482.2 A07.0 T50.A13D 125 011.90 072.2 060.9 014.05 027.9 101 B30.9 A06.1 320.2 B97.5 484.8 A41.9 130.0 013.90 078.19 T50.B12 084.8 040.2 102.2 A25.0 B57.2 123.5 I31.2 J15.5 B27.81 099.59 B08.72 M86.9 005.2 094.82 H59.42 112.2 T79.A11 139.1 J85.1 003.9 008.43 003.0 A82.9 480.3 A08.2 083.2 123.9 070.43 078.4 078.1 B38.4 B40.1 B00.89 034.0 A51.5 012.01 B71 006.4 513 J17 074.3 A56.4 A18.12 A77.49 B95.8 132.9 B55.2 011.15 017 008.42 T50.B93D L03.039 B77.81 126.0 A56.09 077.3 B95.4 484.5 323.71 682 074.0 008.49 B17.11 010.05 A66.8 A85.2 B48.4 B96.5 A51.31 054.42 011.41 A52.8 132.2 A50.45 A04.7 A77.9 B46.5 006.5 115.04 009 A39.82 B37.42 011.0 B08.09 054.73 A44.8 012.84 P36 B85.0 383.21 059.0 040 126.8 T50.B95S 771.0 074.23 323.51 685.0 A26.0 382.01 B01.2 B83.4 A42.82 B00.7 B67.69 015.7 038.41 B94.1 421.0 021.1 098.86 A68 T50.B15A A49.02 T50.A21D 013.22 A32.7 B58.2 124 099.49 B67.32 079.83 121.0 A54.5 A52.3 J12.0 B87.3 070.1 B08.03 132.1 016.55 111.2 T50.A25 090.7 A36.81 A41.53 018.80 A81.01 B69.1 A21.1 098.82 I30.9 002 102.9 016.94 J04.30 A19.8 050.0 017.65 A18.18 A50.43 B93 023.0 A92.5 103 B74.2 032.1 121.8 B85.4 A18.59 A59.02 015.22 A40.3 392 T50.B16D T80.A19S B82.9 A52.15 T50.A93 A30.1 B42.0 053.11 376.00 B48.1 018.04 137.0 033.9 130.5 045.9 131.09 A05.1 A19.9 A77.1 A02.9 T50.A11 125.1 590.01 011.46 A82 128.0 A39.4 139 A99 016.0 041.0 070.0 008.04 B18.1 015.73 B78.7 B34.0 P36.10 B44.1 B39.0 077 095 383.22 A93.0 381.4 062.3 036.89 326 B82 046.72 422.91 099.0 070.30 A54.85 B08.79 016.31 372.03 057.0 013.51 A37.81 T50.B94A 017.73 464.30 T79.A29A A50.9 A54.03 A52.71 730.78 A30.2 J31.2 A02.20 010.8 372.30 A26.8 012.33 008.67 B96.3 B43.9 018.84 A18.52 B58.3 I31.4 A79.89 046.8 T50.B96A B10.89 039.4 B97.81 B05.3 091.8 686.1 115.19 B81.8 B42.81 T50.A95S I38 A69.20 013.96 A06.81 015.2 B05.81 126 070.20 010.84 A93.1 041.82 A56.3 A65 085.9 054.40 093.89 015.54 016.42 084.7 464.31 B05.0 111.9 030.2 A48.1 008.64 072.1 H62.40 B10.82 A06.89 055.1 052 J12.81 466.11 T50.B95 007.2 A38.1 060 A31.1 B34.3 372.04 026.9 M72.6 016.12 027.1 590.2 P39.2 126.9 110.2 011.35 095.1 480.9 013.13 B44.81 004.8 A20.3 013.65 013.8 052.8 I82.A21 382.00 B76.9 A18.10 013.54 A68.0 M89.60 A56.19 116.0 041.43 A52.09 320.82 B25.1 J12.1 A17 036.8 091.3 M89.639 001.0 074.1 A41.3 A03.8 B02.7 B43.8 B97.30 018.96 682.5 682.0 372.20 B87.4 072.9 018.81 J16.0 G03.0 A83.0 041.12 J15.6 321.3 B37.89 012.16 391.2 018.9 B57.41 B58.09 070.5 K65.2 045.03 A98.8 070 095.4 G02 A66.9 T50.B14D 053.29 B33.0 A48.2 031.8 P39.0 099.41 A06.6 A31.9 114.2 J03.90 065.1 730.99 H05.029 A55 A50.7 H67.9 047.8 017.3 054.41 050.2 127.0 016 B34 018.94 011.34 033 056.0 115.11 121.3 A42.81 A24.1 079.50 B76.0 T50.A93D 072.71 099.51 015.95 A15.9 012.10 059.12 B07.0 T50.A13S B96.29 017.34 B00.2 B60.13 P35.9 078.2 049.8 121.9 B44 598 103.0 A05.0 H04.309 021.0 041.8 B22 B02.31 730.74 014.81 012.83 372.21 011 B91 A77.2 B58.01 J15.9 T50.B13D 015.51 054.49 B33.3 026 A54.33 A29 053.21 A51.39 682.4 488.09 321 T50.A12S T50.A22S 088.0 032.85 A00.9 008.8 073.8 730.79 A80.4 B42.9 A41 A71.9 A80.1 093.23 567 039.8 A06.0 H04.429 P37.0 015.23 078 112.82 041.02 115.92 A41.52 B88.0 B96 022.2 A36.89 A52.9 B35.9 I31.8 A38.8 013.92 I82.B23 H66.90 015.94 M35.8 G06.1 391 B46.4 017.86 A02.25 A17.83 122 B90.2 B19.11 T50.A96A T80.A11D A43.0 A74.81 016.51 056.00 A18.39 472.0 102 099.5 A67.0 H70.229 323.4 J09.X9 117.4 015.71 A80.0 B47.1 041.5 126.2 J21.8 484.7 I33.0 016.13 B95 016.95 054.71 043.2 422.93 045.10 128.8 B57.1 059.10 B57.49 091.4 038.2 016.61 021 567.31 B65.8 079.81 B37.81 730.91 018.86 B65.3 372.0 B02.23 B39.5 A48.0 B18.8 482.0 381.10 005.3 017.6 464.50 A50.6 P37.8 T50.A96 A52.11 B67.39 H04.339 T50.A14A 039.3 421 T50.A24S B16.1 B51.0 I09.2 053.19 015.56 T79.A22A T80.A19 A52 G05.4 051.2 A44 B33 079 A67.1 380.10 T79.A12D B27 053.22 103.2 771.5 A37.80 B27.19 I82.B11 018.8 A22.0 A18.83 A40.0
Infections-Respiratory	017.10 013.95 017.86 A17.83 J12.9 013.42 016.51 011.80 J15.1 017.83 017.42 A18.39 A19 010.91 J09.X9 017.81 015.71 017.30 013.83 J03.00 T50.A16D A15.8 016.32 017.20 015.62 017.31 B25.0 J20.6 482.32 J21.8 017.02 484.7 016.13 012.31 016.95 017.44 017.82 016.71 013.61 016.60 T50.A15A 011.33 011.84 018.93 016.61 011.10 485 015.50 018.92 018.86 J01.21 J12.3 017.70 482.0 018.01 464.50 011.31 J11.82 482.42 010.06 014.01 J01.20 016.36 J15.8 015.56 T80.A19 013.53 010.14 A19.0 011.93 013.44 A18.4 A17.9 017.22 T50.A15D J20.9 J03 017.80 T80.A19D 011.91 018.85 A18.83 013.06 016.03 012.85 A17.89 J18.1 012.21 015.01 482.82 011.42 462 017.32 J20.0 482.31 017.74 015.14 012.00 J01.10 487.1 012.06 483 012.86 017.93 J09.X1 011.30 016.24 J02.0 J15.212 016.73 010.11 016.66 J10.81 013.62 016.30 480.0 A18.6 013.10 016.34 017.25 017.13 A18.02 J05.10 466.0 013.01 J11.00 015.61 J06.0 010.85 017.76 012.81 015.04 480 011.70 A18.13 015.05 016.93 A19.2 013.80 012 A15 016.05 488 A18.85 015.53 011.23 012.04 J01.00 016.45 015.11 013.14 482.89 010.02 A18.54 013.93 J10.08 J01.41 011.96 J07 011.26 015.10 J11.08 018.05 466 J05.0 461.8 017.33 014 015.55 011.43 011.01 013.46 015.21 015.26 016.53 015.20 012.03 011.92 J10.00 016.04 013.60 J21 010.15 J01.01 010.94 010.04 461.2 J15.7 015.12 J02.9 464.51 016.14 017.41 018.82 013.52 011.64 011.83 J85.0 A18.09 482.1 J11.1 482.84 011.24 011.04 J15.3 483.8 010.01 010.83 J15.20 J20.1 A15.0 017.63 J22 016.90 013.26 A19.1 010.16 014.06 016.92 016.35 016.54 010.96 J00 015.75 016.91 J18.9 T50.A16 012.35 016.01 015.76 017.92 A18.31 010.93 012.13 018.95 016.21 T79.A19 013.23 016.41 012.14 482.49 014.85 011.72 017.01 A17.82 J10 488.1 011.71 487.0 J09.X3 T50.A16A 013.66 011.53 013.55 015.83 A17.81 J01.80 015.74 J12.89 B44.0 J18.8 464 482.83 017.06 A18.89 016.65 011.14 J10.01 015.66 J11.2 017.90 013.31 012.34 018.91 J08 010.80 J20.5 A16 I82.A19 011.76 017.24 011.50 013.20 016.16 016.50 015.03 015.65 012.32 015.70 016.52 A15.5 461 016.44 A18.14 015.52 A22.1 011.82 A18.53 460 J01.11 486 017.66 480.8 464.10 J02.8 012.30 J10.89 J21.9 J85.3 012.23 016.76 017.84 016.02 465 015.92 482.2 014.03 J16.8 014.05 011.90 J18.2 018.83 A17.0 017.40 484.8 013.45 464.20 013.90 014.00 J11.83 013.11 011.54 482.41 017.56 J15.5 012.22 482.30 J18.0 015.90 013.12 011.20 T79.A19S 013.81 013.33 J85.1 480.3 J01.40 015.85 012.02 013.43 016.74 017.94 010.95 017.64 461.3 011.95 012.01 016.46 A15.6 513 J18 011.65 J17 013.21 A18.12 J01.31 A17.1 011.15 015.84 017 013.00 016.63 014.04 013.40 011.94 A18 J01.91 484.5 J06.9 J20.4 464.00 461.1 010.05 012.36 010.86 A18.50 J03.80 011.41 015.15 J01.30 016.33 483.1 T79.A19D 013.32 012.84 012.05 017.52 011.06 J01.90 010.12 015 013.15 J14 011.45 J15.211 J09.X2 016.20 015.02 013.04 J01.81 014.86 011.05 013.82 487.8 015.16 011.66 A18.15 J10.82 017.53 010.90 M79.A19 017.43 013.22 012.11 J03.91 J12.0 J21.1 484.6 A18.2 017.15 J01 011.00 013.03 017.16 J12.2 016.55 J15 016.70 018.80 488.0 013.41 013.25 017.04 016.94 011.32 013.64 J04.30 J09 465.9 A19.8 017.65 A18.18 J03.01 480.2 A18.51 012.20 016.72 J15.29 016.40 010.13 016.00 A18.59 015.22 016.75 018.00 017.51 513.1 T80.A19S 013.86 015.00 A18.82 017.50 018.04 018.06 013.85 J16 011.55 A19.9 J20.2 015.06 011.22 011.46 011.73 J06 016.22 010.03 013.30 017.60 015.73 017.05 012.25 017.46 016.10 T50.A15S 012.82 J04.2 016.31 013.51 A18.81 013.36 J12 017.73 017.91 464.30 018.03 010.10 A37.91 016.43 013.16 010 481 017.35 A18.17 015.86 011.56 J20.8 T50.A16S 011.52 017.72 010.00 011.36 015.82 012.33 011.03 483.0 A15.4 018.84 013.35 A18.52 011.51 012.24 018 J11.89 J03.81 J15.0 013.96 G40.A19 010.84 017.95 010.92 015.54 464.21 016.42 464.31 016.25 A48.1 011.63 464.01 464.4 012.12 T50.A15 J04.0 513.0 015.60 J20 011.11 484 466.11 011.25 013 J12.81 017.23 015.96 016.12 013.63 484.3 461.0 017.03 011.35 480.9 J04.10 013.13 017.12 013.65 015.63 015.80 015.93 A18.10 A18.7 T79.A19A 013.54 J04.11 482 016.62 011.75 A17 J12.1 016.56 J10.83 017.36 011.13 J10.1 011.85 016.64 018.96 011.61 015.91 015.64 482.81 018.81 J16.0 013.05 J20.7 011.86 015.81 J15.6 017.71 012.16 A15.7 011.40 013.50 J02 018.90 016.26 013.91 J15.4 017.14 482.39 A18.32 482.9 A18.11 J03.90 016.11 015.24 465.8 011.60 010.82 487 017.96 013.94 012.26 013.34 016 017.55 018.94 011.34 011.21 014.82 018.02 015.95 J20.3 017.26 017.00 A15.9 012.10 017.54 J11.81 013.56 015.72 013.02 017.34 016.15 J10.2 012.15 011.74 480.1 J05.11 011.44 017.45 014.83 015.13 017.11 014.84 A18.01 010.81 466.19 J11 015.25 A18.84 016.06 016.23 017.21 014.81 A18.16 012.83 J85.2 014.80 017.75 011.16 484.1 011 017.61 J15.9 017.62 015.51 011.12 463 J05 J04.31 A18.03 J85 016.96 482.40 012.80 013.24 013.84 J04 464.11 011.62 J19 017.85 014.02 J21.0 015.23 011.81 T80.A19A J13 013.92 461.9 015.94 011.02 465.0

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Injuries	S06.9X4S T84.490D T63 S63.621D S82.232C S65.391S T85.614 S25.809D T85.398 S72.346 S83.011A S60.212A S66.526D T80.59X S52.232D S53.026A S82.115P S56.822 S86.391D T63.614D T50.992S S61.221S S19.9XXA 943.23 T23.179 S71.131 T80.410S S93.129 T40.0X2 T81.83XS S72.436R S63.433D T24.591D 832.01 S72.91XK T24.031D S36.533A S56.196S T22.232A T24.332D S92.355K S59.129 S31.112 T78.3XX S66.120A T81.516 S21.442D S82.043P 803.50 S63.232S T53.0X4A S92.123A S36.020D S72.019A T63.511S S82.864R T65.831S S63.657D S14.157 T04 T84.620 S22.040K S56.892D S72.441A T56.1X1D T83.85X T53.7X3 S68.123A T47.1X6S T26.71XA S14.4xx S89.002D T53.1X1 S62.307S T65.213S S82.242M T22.741A S62.023D T46.6X1 S32.131K S52.515C T65.0X3S S46.012A S52.265C S92.221B S65.111A S06.1X1A S60.461 S61.549D S36 814.03 S24.151A S50.811A T62.1X1S S42.446P S52.264G T24.491A S52.042A S92.599K S06.4X9A S92.416D T20.411A T81.507D S12.600B S82.492P S21.351S T45.1X4S S32.000 T75.4XX T82.391 T43.623 S36.290 T54.3X1S S42.209K T56.3X3D S59.222 S99.829S S09.19XD S34.22XD S63.652A 942.45 S32.471A T40.3X2 S60.444D S82.146S S82.822K S50.10X T83.022S S56.128S S05.91XD S82.874Q S42.111D S25.402A T82.322 S62.614S S86.929S S90.464D S74.00xA T65.4X2 T61.784D S83.30X S32.456B T53.93X T24.501A S37.69XA S37.091D S63.022D S80.849S T46.991S S61.021 T49.0X5 S90.411D S30.826 T63.834 S64.494A S42.033D S32.058D S42.191D S52.332C S31.110S S82.871M T43.4X5S S95.911S 861.20 S20.309A S01.01X S13.171D S72.366M S82.154B T79.5XXA T83.69XS S09.90x S00.252S S83.096S S01.90XA S72.031K S63.439A S06.365 T50.Z92 T25.139 S09.312A T50.Z11D S37.031 S82.426A S82.022K S95.809 S12.300K S35.338S S92.244D T23.799 T28.412 S82.254 S62.312 T22.022S S02.118B S06.6X2D S60.940S S31.20xA T17.408D S09.312D S52.399F S62.251K T63.071D S82.464Q S52.243J S82.465Q S82.401N T49.8X6A 914.3 S55.212 S59.102K T86.23 S96.899 S22.050S S41.112D S50.11XA S52.272M S72.416C S82.876G S22.039D S42.144G S63.227A S66.518A S72.416S T85.511A T48.4X4 S82.034R T20.69XD S82.62XP S42.112B S52.244 S92.031K S12.151K S42.216 S41.031A S15.202D T23.079D S39.91XS T19.4xxA S82.291A S92.491K S01.449S S52.361J T63.813S T63.713A S72.434J S82.016D S99.029B S22.002A S80.919D S83.231D S82.209H S90.933 T78.07XA T53.2X1S S20.461 T36.7X2 927.8 T82.897A S72.365F T20.72x S63.065 S72.111B 821.00 S63.432D S65.911D S96.102A 944.46 S30.857A S83.001 S22.032D S87 S93.324D S15.9XXS S41.031D T63.93XD S82.154 S60.031 T23.469A S21.429A S52.282 T71.223 S62.338G S82.443D S67.90XS S92.111P 887.7 S15.121D 917.7 S66.516S S70.12XS S23.143A 956.0 T39.8X3S S72.012D S90.01XD S61.205D S82.242S S82.843M T46.6X6D S39.002A S62.331B S09.312 T45.2X1S S82.843D S86.111S S20.02XA S42.335A S59.299A S20.112S S81.019 S32.120S S83.123A S92.331G S50.912 S50.02XA S67.194 S02.630K S82.033P S66.002A S61.234S S61.217D 901.1 810.12 S89.392P S60.342 S52.265N S60.471 S00.451D S53.091S S72.041D S59.101G 923.03 T24.031A S01.81X S89.101K S51.842A T52.2X4 S92.323D T50.4X5S S82.234J T22.351D S76.311A S52.044R S82.872M S83.262S T55.1X2 T71.234A S82.156K T38.4X2D S31.145D S62.399P S63.217A T41.0X2 S92.411D S63.121D S52.225 S56.329D T23.091A 866.10 S45.011A S36.99XA S72.361A S52.343F 949.4 S75.811S S81.822D S82.124P S72.442D S46.891 S92.326D T25.219A S72.425R S42.251B S66.120S S88.021S S27.69XD S52.513J S60.569D T63.832A S65.508S 935.1 S82.113N S62.329D T83.39XA T63.823A T61.04XA T81.532 S42.035 S02.602A S52.609A S56.418D 806.31 S82.253Q S98.912S T21.31XS T37.5X6S S09.0XX S72.364D S25.192S S25.511A S59.919S S62.637B 812.19 T33.519A S00.221 S01.401 883.1 T24.501 T18.120S T14 T48.0X5D S40.862D S30.870S S92.242G S48.021A S52.035S S52.321B S52.334R S62.620P S42.409A S43.402S S62.513D S82.126A S92.051D T43.226A S62.637A T21.33xA S62.644P T48.1X6D S45.392 S52.223A T45.1X4D S92.356K S72.052K S52.365C T65.6X1A S72.341H T82.827D 844.8 S89.312K T37.8X4 S34.101A T84.121A S10.92XD S61.344D T20.63X S92.513 T23.321A S62.226P S12.040S S93.409S S03.02XA S45.901D T39.1X1A T81.519D S62.102S S63.391S S37.022A S62.601 T43.601 S15.209S S46.109D S95.999S S52.381D S83.242A T42.6X1S T17.890D T43.605S S82.136S S72.102M T51.1X2D S04.041A S43.025A S82.102Q S65.409S S92.243G S22.49XA T22.362S T53.4X4 S61.111D S11.11X S32.402G S42.123S S62.300G S36.92XD S62.609A T53.92XD S20.169 S42.223 S82.391C S68.619 T71.21X T63.414S T52.8X3S S85.142D S81.841 T44.1X2 T82.838 S82.391M S61.253 S04.10X S93.302 S92.422 S52.202C S62.211K S98.922D S37.051A S72.302P S92.226P S92.101G S95.902S T45.2X6D S62.031D S26.92XS S72.144 945.16 S65.508A S75.911A S49.031S S09.399 S70.922 883.0 S15.199A S99.191K S82.436B S37.899 S72.302B S04.041D S21.149S S28.211D S52.379S S62.145K S32.615A S41.121A S80.822A S20.109A S92.061P T21.60XD T36.93XD T24.239A T40.1X2A T83.86XA S01.82X T65.823 T65.94X S33.101S T85.868A S92.251B S02.670S S96.029 S95.101S S29.099S S60.322D S77.10XD S92.136P 863.93 S92.334B S63.228D S82.142R S52.246K T20.619D T26.31XA T25.391D T24.512S S82.423 S90.934 S82.461K S92.224 863.54 S82.866J T53.3X1A S11.95X T51.2X4 S62.337P S70.241 T85.122S S62.92XG 915.4 S62.311A T63.634S S72.322B S60.559D S82.192P T41.205D S89.099P S07 T65.214A S52.511G S36.30XA S65.091D S66.313 S01.422D T36.6X2S T50.991 S75.999D S92.401P S26.91x S85.131 T87.0X9 S52.326N T17.910S T50.4X1 S65.999A T49.7X4S S55.811 S32.509G S62.164D S91.141A T23.479S S72.90XS S62.335S S93.333S S43.91XA S52.263F 913.1 S82.862S S56.122S S76.011 T83.25XA S31.122D S62.186B 943.31 S92.351B S10.14X 945.36 S70.369A S31.639 S89.199G T56.1X2D S75.199S T52.4X2A S31.551S S52.132B S62.308K S62.629P S61.541 S89.312P S72.451A S82.022F S93.602D S66.510 T36.4X3D T23.442A S32.442 S37.818S S66.911D S92.343S S30.842S S99.129G S63.093 S12.291K S32.601G S68.711D T45.695 S27.53XD S22.068K S92.233D T80.A9XA S90.02XD S00.04XD S62.224K S82.442K S04.032A S42.482P T49.0X1S S75.091S S56.019A S52.026N S82.846A S52.261K S68.114A S20.222A S92.513B T41.41XA S52.611H S14.107D S92.141S S52.336F S32.008B S12.112S S42.331G S63.251S S82.436Q S30.846 S52.512Q S82.453M S52.002R T23.442S S01.339 S06.9X4 T63.023S T25.412A T36.5X6 S42.265B S53.142A S92.533P T65.292A S42.296G T83.030A S15.191S S72.136F 942.50 S21.101 T67.9XXS 942.01 S96.891D 821.20 T45.515D S72.452H S86.219A S06.354D S20.349D S52.265F S11.24X S72.413A T24.632D S72.423S S66.197S T47.8X6 S12.491K S56.291D S32.030G S92.332G S20.20xA S42.036A S32.050G S75.222S S63.258 S52.099C 813.54 S95.812A S10.95XD S82.302R S86.309A T75.89X S63.619S S00.411 T54.2X3S S82.54XR T83.84X T24.601A S00.449A T37.0X2D S72.324Q T17.400 T59.813 S92.144P S72.322S S75.101 T59.7X2A S92.113S T22.159D S92.236D S72.121M S63.301A S89.399P S50.10XD S68.123 S62.650S T23.641S S31.655D S55.819D T21.00X S58.029A S68.421A 801.23 T38.891S T21.79xA T22.091S S42.362A S89.221G S62.022P T40.696D S97.119 S46.191S S53.192S S00.521 T53.0X1D T63.633S S52.611J T63.443 S36.438A T43.214A T81.512D S02.40CA S06.5X9A T82.521 S61.142A S62.111S S82.55XB S36.409D S99.131 S61.324S S61.152A S55.812S T50.6X1D S62.151 T56.891 T50.4X3 S00.212D S52.124R T22.142D S98.221S S72.411C S92.422G T71.193S S82.491G S50.861D T44.993A S82.012R S30.92X T23.312D 834.02 S72.462G S63.633S S65.502A S61.348 S72.115R T46.5X2D T26.12XD S62.610D S37.429D S82.876J T21.71XA S93.429S S76.929S T49.2X5S S62.342P S62.222B T63.793D S32.421A T24.731A S21.329A S09.0xxS S98.011A S62.515S S72.346H S63.106S T28.911A S63.636 S72.063D S04.042A S62.514B T84.112D S59.202P T56.5X1D T34.512S T36.4X4S T45.615D T24.202A S42.332K S20.479A S72.116N S82.199R T65.222D S53.106A T45.4X3A S92.062D T69.9XX T38.2X1S S72.415B S86.801S S46.121A S91.359D S89.80X S92.346G S82.426Q S82.891Q S92.054P S42.443P S42.296K S53.193S T63.114S S37.591D S92.919B S31.23XS S20.469S S92.522G S24.149 S82.424J S42.125S S99.222G T48.204D S60.473S S09.21XD S62.638A S92.812K T40.904D S82.043M T20.32X S12.391D T21.17XD T22.791D T83.420S S61.243S S62.176S T23.449 S43.121S S62.025P S83.252D S00.01X T22.052D T79.A12D S30.93XD S25.892S S82.422A S20.462D S45.019A S42.463K T63.061A S27.812S T51.3X4 S69.90XS S93.135S S32.444S T23.179A S99.142S S25.502 S56.012D S81.839D S82.092J T50.2X1D S50.322A S00.471S S32.811K T85.860 S61.353A T82.221S T34.3XXD S84.20XD S72.133M T54.2X2 S09.399A S62.251S S76.822S S82.141B S78.911 T83.23XA S93.303 S34.103D S52.599P S21.232 896.3 S06.6X3S T45.7X6 T38.4X4 S82.235D T25.321A T36.8X2S S42.115G S14.135D S72.324R S82.846D S96.999D S63.635 T83.83XD T50.993S S06.4X1D 848.40 S65.811A S66.401S S82.312G S52.311D T16.2XXA S82.102H S52.246C S56.802S S06.384S T65.291A S36.269A S02.621A S83.211A S72.326M T17.598A S36.299 T23.672S S42.156 S52.132E S63.423A S82.431K S66.501A S62.252S S20.342A S42.492K T85.613 S32.409K S01.342A S60.542 S63.312A T67.5XX S51.822A S66.902S T33.90X 805.02 S92.035D T33.02X S83.122D S65.291S S30.0xxA
Integumentary	L10.81 L89.813 709.2 L02.639 R20.8 L02.619 L97.218 L92.8 L21 690.12 L56.2 Q84.0 778.1 521.15 L64.8 L03.123 L06 R23.9 782.8 L94.9 L03.213 L16 L97.503 L89.814 L98 L97.923 L66.3 L97.812 L02.422 L89.514 L02.33 680.9 690.18 L97.529 J70.1 680.0 L97.824 L89.149 757.5 L40.4 L97.413 L51 L63.0 L92.2 L97.504 L93 L24.89 704.00 P81.0 529.2 L02.432 709.01 K08.51 P83.8 L08 L89.124 525.0 L89.129 K05.00 L10.2 L72.2 K08.403 L89.614 K13.29 L03.212 L71.1 522.7 703.8 707.02 L49.7 L02.235 690.8 695.3 705.0 737.33 L89.209 L94.1 L04.2 729 K03.9 L02.239 L89.133 L41.5 523 L29.1 707 L98.422 L89.620 778.3 782.1 L89.610 L41.8 778.0 L40.3 L35 521.09 710.9 L43.2 L03.114 L12.2 L64.0 L81.0 L49.5 L97.205 L97.306 525.64 L26 521.32 L89.103 L92 K08.530 L97.929 528.6 L89.629 L66.1 Q84.3 L89.603 L90.2 L12.0 K08.0 K05.30 695.57 L08.81 L70.3 L97.314 K08.9 L04.8 L50.8 L24.0 L89.503 L20 558.1 M35.9 692.71 L32 L89.009 L58.0 525.42 L97.118 L74.2 L89.40 L97.309 L30 L70 L40.8 L98.498 L69 525.52 L81.5 525.44 L89.501 P81.9 521.00 L63.9 L60.1 K08.52 K02.7 L97.516 528.00 L95.9 L89.020 L23.1 L11 698.9 695.53 L40.53 L03.039 M79.0 L29.2 521.49 K04.3 697.9 L97.424 L71.8 L68.1 680.2 L40.1 L89.011 L24.9 L76.21 K05.21 522.9 L40 525 K05.32 K14.1 L97.321 L89.613 L97.404 K04.90 L82.0 700 K13.23 L03.891 L89.102 L28.2 L01.1 704.2 L89.601 L14 R23.3 521.11 L74.8 L73.9 L81.3 L97.926 L49.1 L85 L91.0 521.13 707.03 L97.209 L44.2 L55.9 L89.300 L81 P83.1 692.7 697.8 L97.121 523.30 L97.106 703 L74.510 521.9 R22.9 L02.214 757.3 L02.435 L94.0 L02.532 L03.316 L41.0 M96.2 695.51 L97.512 L20.89 L89.139 K14.3 L62 525.10 508.0 L02.519 521.02 L97.221 L89.304 L98.493 L20.9 L27.0 522.6 L56.3 L89.42 523.1 L56.9 L21.8 K08.104 690.11 778.2 L98.9 523.41 L03.011 L75.1 L89.110 523.3 L89.120 709.09 L03.323 L85.8 L49.2 522.0 L97.909 525.50 707.19 525.51 698.0 697.1 L89.611 L03.312 K08.531 523.2 L81.9 Q84.8 K03.81 695.54 L73.2 L02 L89.219 L72.12 L97.914 782.61 L97 703.80 L02.221 521.40 L85.2 L89.604 527.3 680 L89.112 L60.9 L83 L89.200 L65.0 L43.0 707.25 L02.434 L36 L87.0 L03.311 695.52 L92.3 L11.1 L72.8 L97.805 K02.61 R20.2 L89.001 L97.822 L49.9 L97.815 L89.203 L97.823 R22.2 525.12 L51.1 L43.3 L92.1 L33 529.0 L85.1 L57.3 P83.0 L89.893 L97.213 L68 L38 L02.215 K14.9 P80.0 K08.50 L04.9 L65 680.1 L89.623 L97.211 L89.529 528.79 525.1 L89.134 L24.6 L02.233 L97.116 L97.402 707.15 757.2 L97.828 778.9 525.67 L02.429 L97.911 707.13 L10.9 529.9 L76.33 L56.8 L89.612 L65.1 K05.11 778.4 L89.212 L97.922 705.8 L97.829 K13.70 L89.101 L75 L81.8 L97.526 705.82 L30.4 K08.101 709.9 L02.539 L74.519 L17 521.81 P83.2 695.56 L02.521 L03.222 521.07 L98.8 K08.55 L44 L21.9 L43.1 729.9 L98.424 L72 521.7 L02.413 L74.1 680.7 L55 L02.234 L97.128 M27.62 R23 L44.9 L89.301 L97.212 K08.59 778.6 L03.319 L92.9 L01.01 L02.02 K08.499 L97.202 K14.6 L72.0 L89.121 L59.9 L02.529 P80.8 L97.323 K03.89 705.89 702.19 L12.30 L73 P81.8 759.82 L02.632 L91.9 L02.416 L97.418 709 521.35 L58.9 L97.328 L02.93 L75.2 L97.429 L89.520 L67.9 M96.5 L08.89 K14.0 521.30 525.66 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M27.69 L02.212 L25 L73.8 L08.82 523.9 704.9 L03.315 525.41 L89.310 L02.13 692.74 L97.406 L87.9 521.2 K02.62 L05 L02.426 L67.1 522.8 521.22 680.4 L68.0 521.25 L97.304 L47 L89.524 L97.326 M79.9 L61 A69.0 L72.3 704.3 L89.143 701.2 L97.325 L03.019 K14.5 L02.838 L97.419 K04.6 L97.109 523.23 L98.0 729.7 525.3 L41.1 L04 K52.0 L03.324 705.2 L03.012 R17 528.1 L97.101 L10.1 729.72 L02.232 L57.5 L89.140 K05.01 L13 P83.6 L48 523.5 L97.305 L97.906 L01 L89.142 707.23 L97.928 L23 L97.522 523.11 L51.3 K08.3 L90.3 694.3 L75.8 L64.9 L44.1 L03.126 L97.225 L85.0 L76.11 L97.324 706 529.4 L02.811 L23.6 L03 L03.327 L97.204 K03.5 523.42 L10 L97.813 L70.8 L03.041 L89.010 M79.89 L97.228 L94.3 695.5 655.63 L97.525 757.8 L97.403 L98.3 L89.214 L89.522 L89.201 782.5 L97.222 521.0 L98.423 L23.0 L93.1 L01.09 L97.904 529.1 705 L89.003 L02.431 L91.8 P83.5 L03.211 L84 L29.9 521.8 L29.0 L67.8 L02.225 L90.0 L89.621 525.61 782.9 K03.6 L74.511 525.7 L04.0 525.72 L02.411 782.4 R22.43 707.20 L97.114 Q82.1 L23.2 L89.311 R22.42 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Musculoskeletal			553.9 M84.574D Q67.5 M84.442S M70.30 M25.761 M46.87 550.00 M60.231 M71.829 M85.622 M84.675A M84.753D M08.429 733.20 M84.472 M60.239 M84.346K 727.6 M12.332 735.1 M84.550K M62.241 M71.062 M66.219 M05.051 M24.275 552 M67.479 755.67 M89.322 M27.59 M25.842 M80.821S M84.753A M84.573P M54.02 718.80 M53.86 M85.58 Q65.00 733.43 717.41 M24.174 718.9 M85.012 M48.58XG M15.9 M10.452 M41.22 M20.21 M84.522K M16.10 M23.041 M66.211 M19 M13.822 M24.231 717.82 M90.871 M87.035 M48.57XD M96.679 M21.40 M32.12 M93.841 718.82 M46.96 M65.341 M11.10 M25.222 M67.279 M80.019S 719.99 M66.172 M84.462K M84.442K M96.639 M80.011S M08.231 K43.7 M08.849 M23.007 M12.212 M48.02 M84.619G M65.171 M67.229 M66.272 M60.819 719.90 M11.049 M84.553A M85.812 M89.312 719.70 M06.811 M12.449 M45.0 M79.4 M26.03 M24.075 M86.151 P13 M24.676 M99.77 M84.651 M10.329 M89.752 M23.91 M05.271 755.30 M80.052 M05.842 M08.829 M96.662 M00.232 M80.069A M85.311 M63 M94.279 M08.839 718.47 M77.30 M80.012G M05.372 M15.4 M62.511 719.04 M89.542 M84.561S M84.572 M94.9 736.05 551.01 M08.469 M94.0 M71.129 M80.011P M99.9 M07.649 M67.832 M05.519 M25.642 M84.533D M54.15 M05.069 M62.259 M84.662K M24.031 M20.001 M90.551 M60.031 M05.60 M61.146 M24.651 M41.112 M93.811 719.12 M89.619 M08.911 M14.879 M08.3 M05.69 M00.162 M05.722 756.55 M05.431 M18.32 M70.951 M80.859G 730.39 M92.12 M48.43X M65.852 M26.00 M23.052 M24.572 M40.14 M80.079D M86.542 M05.049 M65.261 M65.011 M84.663P M60.172 M05.811 M11.822 M71.562 M85.321 M99.21 M67.971 733.1 M84.364P M02.10 M60.074 M83.1 M35.9 M97.42XS M12.529 M05.879 M87.032 M46.38 754.5 M90.672 M50.23 719.50 M85.859 737.21 M12.9 M84.452S M84.443 M11.869 719.45 M93.879 M36.3 719.25 M89.49 M76.899 M08.929 M71.869 M89.042 M70.21 M87.334 M10.451 M26.23 M85.00 M06.831 727 M80.831 M90.852 M76.42 M89.28 M65.332 M86.661 M23.631 M50.823 M75.00 M05.479 M84.379 M10.321 M86.021 M61.129 M79.0 M84.569K M61.229 Q79.4 M08 M62.441 M66.811 M06.859 M54 M45.1 M84.571G M84.672D M23.005 M47.13 M84.612S M84.542 M67.272 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M80.869G M89.032 M24.562 359.5 M60.019 M76.61 M24.371 M87.850 M92.219 M84.432G M13.841 M80.822 M84.474D M85.331 719.16 M25.051 M84.353S M94.229 718.73 M19.032 M84.38XK 717.83 M80.031 M84.632K M94.232 M90.532 737.41 M84.575 M10.349 M86.621 M21.859 M60.20 M61.512 M93.022 M84.649 M10.159 M71.811 M05.762 718.76 M23 M84.669D M48.8X5 719.91 M87.037 M52 M10.022 M84.511P M62.011 M26.31 M47.23 718.4 M31.0 M25.641 M11.219 M65.872 M24.112 M65.141 M21.331 M84.757 M20.092 M80.851D M27.0 M87.151 M99.08 M05.742 M70.971 M97 M84.534S M08.412 M43.8X8 736.02 M84.632A M87.011 M24.021 M61.461 M21.629 718.84 M40.56 M84.369G M87.378 M06.849 M89.157 732.8 M66.89 553.03 M92.299 M42.00 M71.572 M35.8 M02.152 755.65 726.70 M89.8X9 M12.822 M80.042K M84.433G M88.832 M67.411 M23.307 M24.7 M05.759 M67.864 M61.412 M54.08 M10.169 M84.434K M18.50 M24.276 M62.89 M84.833 Q65.4 M40.00 M02.022 M85.329 M60.259 733.10 754.81 M80.80XG M90.542 K08.20 M11.019 718.97 M71.121 756.53 M21.029 M62.131 M26.221 M25.129 M34.82 M86.261 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C84.44 204.10 C44.310 205.32 C49.0 I82.C29 C50.629 200.55 C49.8 D41.00 D05.82 204.81 D48.4 203.1 C81.90 C38.3 C68.8 623.7 209.34 208.91 239.5 C83.86 185 164.0 164.1 C82.46 151.8 201.0 C34.82 235.8 C84.13 198.0 203 202.06 C51.2 200.48 157.1 624.3 D42.1 C34.2 D21.4 204.90 205.91 C44.721 C69.40 164 C82.28 200.5 D01.49 C90.11 C49.A4 C43.60 D02.21 C44.219 C84.08 D30.00 C72.32 D15 C74.01 206.92 C83.13 C7A.020 C81.35 D23.61 202.42 160.1 D31.50 143.1 D31.32 C62.10 200.54 202.43 C81.99 C81.21 D36.10 D35.01 C84.A3 D10.4 C82.23 209.65 C72.21 C90.20 D05.00 C22.1 213.1 Q85.00 D24 173.52 202.11 C34.31 173.6 D13.7 D03.70 190.3 201.08 D15.0 C76.50 D12.6 D41.21 D3A.098 D26.0 184.1 208.2 C84.Z4 C84.10 225.4 C83.79 D39.9 C82.34 145.4 C69.01 C79 201.75 C84.A2 C41 143.9 C84.A9 214.4 D47.02 208.8 227.4 206.1 C15.9 C91.Z1 200.37 C17.3 C83.05 207.2 600.9 C50.222 D01 623.0 C81.20 209.13 D06.7 C09 201.73 C90 C88.8 200.30 C84.90 C40.22 C92.30 201.58 202.57 155 C50.619 D47.Z9 200.72 C82.94 170.2 C34.30 215.8 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D31.41 D12.3 227.1 212.8 221.0 C44.90 C50.111 C81.48 C84.92 C53.8 209.20 174.1 C00.8 202.16 237.7 205.82 C56 Q85.03 C84.45 173.70 151.4 D23.71 C83.18 C92.Z2 'C81.78 205.30 239.2 C96.29 C10.8 200.11 C99 602.3 D16.4 C16.3 C50.829 C71.8 C92.31 200.78 C71.5 230.6 190.1 202.14 C82.16 201.00 C69.52 D12.9 173.89 D15.9 205.8 202.28 D29.21 D19 C82.57 C84.62 C43.0 C81.70 C94.01 C81.08 D02 214.8 C60.8 C83.06 C13.9 231.8 C72.59 C90.32 C50 187.8 D14.1 202.88 C51.9 202.81 C83.36 C44.509 C44.619 D04.0 D26.9 D37.8 214.3 C25.0 C46.2 182.8 C75.5 D07.30 200.38 C70.9 D15.2 188 C84.A1 C44.391 C84.02 202.26 173.81 C88.4 C91 D29.31 C94.6 C57 202.4 200.34 Q85.1 218 236.9 173.11 C18.7 C31.3 201.25 C14.8 D22.22 D35.5 C71.6 C90.21 C43.62 C49.6 236.5 188.0 C31 C22.9 C50.212 C57.7 C93.02 171.0 201.76 C00.5 C25.1 213.4 200.57 C82.64 C84.98 D35.3 D49.512 C67.1 D04.10 C83.14 C75.9 200.23 200.26 161.0 C78.1 200.7 C82.85 D31.22 C83.75 D21.11 200.83 200.43 C57.4 D10.7 146.5 D49 C44.510 C57.11 238.0 C50.021 196.3 D46.A D16.31 C78.39 569.0 D39 161.2 C25.3 C30.0 C01 D31.31 D36.14 201.46 C94.81 140.4 150.3 C91.A2 D16.02 D13.2 C47.10 C26.1 160.8 D23.10 173.8 D37.1 C44.701 C11 D25 C63.8 C94.00 D17.24 209.74 C02.9 C91.61 C28 205.02 D21.0 171.6 C17.9 210.9 174.0 D21 C67.4 C50.821 C49.5 173.7 C92.11 209.73 C84.67 C74 C7A.095 219.8 161.8 C06.9 202.75 200.80 224.9 C84.73 C88.2 D17.79 201.21 208.90 152.1 D03 147.8 186.9 C50.622 198.6 229.9 C49.A5 D22.62 203.80 C40.32 C63.9 C81.33 C96 209.6 C87 202.86 C43.30 207.01 D35.1 164.8 238.73 201.62 C96.21 D04.71 171.4 201.41 141.0 C91.60 I82.C21 206.80 189.8 208.21 C82.03 D03.52 D18.09 C25.7 162.0 C38.0 202.72 C82.41 C82.62 173.39 C72.41 202.00 C03.9 229.8 173.40 224.4 213.3 216.3 209.14 C83.83 C16.4 C75.4 202.05 C44.191 213 200.13 D41.11 C69.50 192.1 200.75 D13.1 D48.3 C00.2 C80.0 C81.09 C83.89 195.8 C93.Z0 N40.0 C30 C92.A0 C00.1 C34.10 200.1 174.2 173.71 158.0 D07.61 C84.91 156.1 C84.12 C91.42 D00.07 221 D35.6 225.9 624.6 233.31 D19.1 C91.A0 C05.0 192.3 211.4 C82.45 160.3 622.10 211.5 C7A.011 D10.0 204.0 C81.42 201.26 D23.30 C02 201.91 C40.90 C78.02 C43.21 C44.222 C91.62 239.3 237.71 239.6 230.8 202.8 232.0 C44.89 C81.12 C7A.021 C96.Z 200.01 202.51 N89.3 173.09 D27.9 156.9 C94.82 148.0 197.4 D36.7 202.02 C03.0 189.9 201.53 205.0 D00.02 273.1 199 200.85 E71.448 C50.121 202.20 D48.2 C62.02 149.1 C83.00 C50.321 173.99 D44.2 173.1 C22.7 D44.6 208 C82.56 157.0 170.7 D24.1 D14 C71.4 600.90 C85.98
Ophthalmological		H34.8332 H50.812 H10.439 H35.111 H53.043 364.5 H50.32 H44.812 H01.112 H05.243 H26.493 H10.221 377.62 362.89 H49.43 H18.811 364.71 375.13 365.59 365.89 370.3 H40.51X H44.21 370.24 375.14 H25.23 H17.00 H47.631 H05.342 H21.323 H50.811 H59.022 364.8 H21.229 H20.022 H02.134 H15.022 H46.02 H47.211 H31.111 H59.322 H35.3133 H11.032 H11.432 H16.072 H40.10x2 371.73 370.03 H11.10 362.31 H02.734 H44.753 369.3 H16.142 H40.63X3 H33.051 H18.739 369.05 360.8 H31.092 H52.532 H18.892 H17.03 H04.223 H01.133 371.20 H27.112 H44.621 H20.813 H53.033 367.20 369.08 372.9 H02.871 H40.1310 H40.51X0 H15.091 H04.302 H01.023 H31.303 H26.119 H40.1114 H54.2X1 368.31 H15.813 H35.463 H05.812 H26.103 H04.011 372.4 364.53 H10.511 H39 H40.1192 375.22 H20.012 H31.022 H35.052 H40.149 362.9 H40.241 363.70 H34.812 H53.003 H26.069 H18.833 H18.223 H16.132 H47.312 H47.333 H01.019 H21.342 H02.30 H20.821 H40.53X3 H02.104 H02.839 H05.031 H59.343 H16.061 H16.071 H34.02 377.10 371.45 371.60 H18.623 369.75 H02.209 H33.102 369.60 H50.50 371.51 H40.032 H40.2214 H33.22 H05.53 H05.813 H44.649 H54.1224 H02.439 369.66 H40.049 H40.51X1 H40.10x H02.054 H34.00 H50.15 H18.55 H15.821 H44.511 H49.813 H40.53X0 372.56 H02.136 H21.1X9 H53.023 H04.123 H02.89 H18.422 H31.123 H02.036 H20.021 374.54 368 H26.412 H40.60X3 H46.9 368.12 H57.13 H25.811 360.40 H40.62X4 371.58 369.01 H10.413 H16.309 H26.042 H44.431 H49.02 H53.031 362.6 H11.152 H35.439 362.36 H44.131 H35.3114 H26.123 H40.42X3 H53.132 H53.133 366.19 H40.1111 H08 H44.2C2 H53.433 H05.023 H50.69 H04.541 360.34 H04.212 H05.263 H11.133 H31.411 H18.232 H30.111 371.54 H04.023 H40.61X H35.172 H02.203 362.24 H33.032 H40.32X4 H44.712 377.52 H21.319 H20.22 H02.409 H10.12 H15.812 366.10 H18.9 H52.201 H50.022 H11.423 H34.813 H54.60 H57.051 H18.062 H40.63X H44.2A3 H44.539 361.10 H27.133 368.16 H40.233 H30.133 H43.813 H00.023 H02.109 H18.712 H57.8 371 H47.149 H15.129 H40.62X1 H10.239 377.32 H00.011 H44.723 H10.223 H40.139 H18.312 H35.322 H49.01 371.0 H02.735 374.87 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Table S8: Feature Definitions (Total number of features used: 380)

Feature name	Explanation	n_{features}
feature scores relative to phenotype score	Mean p-score of **feature** codes within sequence divided by general p-score of **feature**	26
feature scores relative to whole score	Mean p-score of **feature** codes within sequence divided by mean p-score of all codes in the record	26
aggregation score	aggregation of the p-scores in the record	13
high scores proportion	proportion of codes with very high p-scores among all codes in the record	1
low scores proportion	proportion of codes with very low p-scores among all codes in the record	1
dynamics of mean score	mean p-score of second half of the record divided by mean p-score of first half of the record	1
dynamics of geometric mean score	geometric mean p-score of second half of the record divided by mean p-score of first half of the record	1
dynamics of st.dev score	standard deviation of p-scores of second half of the record divided by standard deviation of p-scores of first half of the record	1
dynamics of score range	range of p-scores of second half of the record divided by range of p-scores of first half of the record	1
dynamics of score skew	skew of p-scores of seconf half of the record divided by skew of p-scores of first half of the record	1
aggregation relative to phn score	aggregation of all **feature**'s mean scores divided by corresponding general p-score of **feature**	9
aggregation relative to whole score	aggregation of all **feature**'s mean scores divided by mean p-score of all codes in the record	9
predicted risk from pfsa model	predicted risk from pfsa model	1
predicted risk from seq model	predicted risk from seq model	1
predicted risk from pscore model	predicted risk from pscore model	1
predicted risk from rare model	predicted risk from rare model	1
age at screening	Patient age at the moment of the screening	1
feature proportion	Ratio of number of weeks with the codes of a given phenotype to the total number of weeks in sequence	26
feature prevalence	Ratio of number of weeks with the codes of a given phenotype to the number of weeks with any diagnosis code recorded	26
feature first incident	Time interval from observation date to the first phenotype code, normalized by record length	26
feature last incident	Time interval from observation date to the last phenotype code, normalized by record length	26
feature mean position	Mean time position of phenotype codes in the record, normalized by record length	26
feature streak	Length of the longest uninterrupted subsequence of weeks with the codes of a given phenotype recorded	26
Max/Mean/Std/Range intermission	Maximum/Mean/Standard Deviation/Range of the lengths of subsequences of consequent weeks with codes	4
Max/Mean/Std cluster	Maximum/Mean/Standard Deviation of the lengths of subsequences of consequent weeks without codes	3
Max/Std/Range prevalence	Maximum/Standard Deviation/Range of the phenotype prevalences	3
Density of DX Record	Proportion of weeks in a record observed where at least one DX code was recorded	1
feature	Sequence Likelihood Defect for a given phenotype	26
feature neg llk	Negative LogLikelihood score for a given phenotype	26
feature pos llk	Positive LogLikelihood score for a given phenotype	26
feature llk ratio	Ratio of Positive to Negative LogLikelihood score for a given phenotype	26
Mean Δ	Mean Sequence Likelihood Defect	1
Std. deviation Δ	Range of Sequence Likelihood Defects	1
Range Δ	Standard Deviation of Sequence Likelihood Defects	1
Mean neg llk	Mean Negative LogLikelihood score	1
Range neg llk	Range of Negative LogLikelihood score	1
Std. deviation neg llk	Standard Deviation of Negative LogLikelihood score	1
Mean pos llk	Mean Positive LogLikelihood score	1
Range pos llk	Range of Positive LogLikelihood score	1
Std. deviation pos llk	Standard Deviation of Positive LogLikelihood score	1
Mean llk ratio	Mean LogLikelihood score ratio	1
Range llk ratio	Range of LogLikelihood score ratio	1
Std. deviation llk ratio	Standard Deviation of LogLikelihood score ratio	1
high scores proportion	proportion of codes with very high p-scores among all codes in the record	1
low scores proportion	proportion of codes with very low p-scores among all codes in the record	1

[*] Δ: Sequence Likelihood Defect (See Methods)
[†] neg llk: loglikelhood of observed sequence being generated by the model inferred from control (See Methods)
[‡] pos llk: loglikelhood of observed sequence being generated by the model inferred from positive (See Methods)

Table S9: Proportion of 0's, 1's and 2's on average in trinary encodings with 95% CI

cohort	sex	proportion of 0	proportion of 1	proportion of 2
control	Female	0.879 ± 0.002	0.013 ± 0.001	0.106 ± 0.002
control	Male	0.891 ± 0.003	0.012 ± 0.001	0.095 ± 0.003
positive	Female	0.858 ± 0.040	0.015 ± 0.013	0.126 ± 0.038
positive	Male	0.873 ± 0.037	0.014 ± 0.012	0.111 ± 0.035
TOTAL	Female	0.879 ± 0.002	0.013 ± 0.001	0.106 ± 0.002
TOTAL	Male	0.891 ± 0.002	0.012 ± 0.001	0.095 ± 0.002

Table S10: Out-of-sample performance achieved (mean AUC) when training dataset is balanced (Note: performance degrades as we attempt to train with more balanced data, $e.g.$, downsampling ratio of 1 is the case where we sample the control cohort to use only as amany patients as in the positive cohort)

sex	downsampling ratio	all patients	age $65+$ years	age < 65 years	frail
Female	1	0.755	0.715	0.694	0.732
Female	2	0.756	0.723	0.700	0.736
Female	5	0.768	0.735	0.727	0.752
Female	10	0.781	0.750	0.737	0.769
Female	20	0.772	0.750	0.728	0.759
Female	40	0.790	0.760	0.743	0.772
Male	1	0.724	0.665	0.690	0.721
Male	2	0.743	0.701	0.698	0.746
Male	5	0.754	0.708	0.722	0.761
Male	10	0.751	0.711	0.718	0.757
Male	20	0.759	0.718	0.725	0.759
Male	40	0.759	0.714	0.729	0.759

Table S11: Cohort Sizes

sex	cardiac event within week	n_{positive}	n_{control}	$n_{\text{high risk}}$	n
M	2	385	185528	146782	185913
M	4	464	185528	146782	185992
F	2	337	258981	204170	259318
F	4	418	258981	204170	259399
	Total	882	444509	350952	445391

Table S12: Out-of-sample predictive performance to predict MACE 4 weeks after surgery in sub-cohorts with pre-existing conditions

Pre-existing phenotye	Female CCoR	Female RCRI	Male CCoR	Male RCRI
Allergic	0.77	0.71	0.81	0.78
CNS	0.80	0.67	0.89	0.75
Cardiovascular	0.78	0.69	0.80	0.67
Development	0.77	0.83	0.86	0.68
Digestive	0.81	0.73	0.80	0.71
Endocrine	0.80	0.69	0.80	0.67
Frailty	0.78	0.69	0.85	0.73
Health Services	0.81	0.71	0.83	0.71
Hematologic	0.80	0.72	0.85	0.74
Hypertension	0.77	0.68	0.80	0.66
Immune	0.81	0.71	0.82	0.70
Infections Fungal and Other	0.80	0.76	0.84	0.68
Infections General	0.80	0.75	0.84	0.68
Infections Respiratory	0.76	0.64	0.83	0.63
Injuries	0.79	0.73	0.84	0.69
Integumentary	0.78	0.69	0.80	0.72
Metabolic	0.80	0.70	0.82	0.70
Musculoskeletal	0.81	0.71	0.83	0.70
Neoplastic	0.87	0.75	0.78	0.68
Ophthalmological	0.79	0.69	0.76	0.65
Otic	0.79	0.75	0.84	0.62
PNS	0.80	0.70	0.84	0.73
Psychiatric	0.85	0.74	0.89	0.72
Reproductive	0.80	0.70	0.82	0.79
Respiratory	0.81	0.70	0.83	0.67

Table S13: Out-of-sample predictive performance in sub-cohorts stratified by age

age	gender	auc CCoR	auc RCRI	n_{positive}	n_{control}
45 - 55	F	0.59	0.58	3	9056
45 - 55	M	0.89	0.79	5	7027
55 - 65	F	0.80	0.66	31	27256
55 - 65	M	0.78	0.63	39	20244
65 - 75	F	0.81	0.73	34	14235
65 - 75	M	0.73	0.58	31	9635
75 - 85	F	0.70	0.65	25	8515
75 - 85	M	0.79	0.71	36	5164
85 - 95	F	0.80	0.67	8	1578
85 - 95	M	0.75	0.48	12	847

Table S14: Out-of-sample* performance for predicting MACE with 4 weeks of Hip or Knee Arthroplasty (Primary Endpoint) at 99% Specificity: CCoR vs. RCRI**

sex	cohort	model	sensitivity	PPV	acc	LR+	LR-	AUC
Female	< 65	RCRI	0.01 ± 0.02	0.008 ± 0.000	0.987 ± 0.006	0.04 ± 0.1	1.00 ± 0.02	0.639 ± 0.039
Female	< 65	CCoR	0.14 ± 0.06	0.047 ± 0.004	0.987 ± 0.006	14.12 ± 1.1	0.87 ± 0.06	0.775 ± 0.035
Male	< 65	RCRI	0.07 ± 0.03	0.025 ± 0.003	0.987 ± 0.000	7.42 ± 0.8	0.94 ± 0.03	0.682 ± 0.034
Male	< 65	CCoR	0.15 ± 0.06	0.065 ± 0.003	0.987 ± 0.006	19.94 ± 0.9	0.85 ± 0.06	0.783 ± 0.030
Female	65+	RCRI	0.03 ± 0.01	0.012 ± 0.002	0.987 ± 0.000	3.39 ± 0.5	0.97 ± 0.01	0.664 ± 0.028
Female	65+	CCoR	0.09 ± 0.06	0.036 ± 0.004	0.987 ± 0.006	10.70 ± 1.1	0.92 ± 0.06	0.771 ± 0.025
Male	65+	RCRI	0.03 ± 0.01	0.011 ± 0.001	0.987 ± 0.006	3.17 ± 0.4	0.98 ± 0.00	0.661 ± 0.026
Male	65+	CCoR	0.09 ± 0.05	0.031 ± 0.002	0.987 ± 0.006	9.09 ± 0.6	0.92 ± 0.05	0.762 ± 0.023
Female	all patients	RCRI	0.05 ± 0.01	0.016 ± 0.003	0.987 ± 0.000	4.67 ± 0.8	0.96 ± 0.01	0.688 ± 0.023
Female	all patients	CCoR	0.13 ± 0.01	0.044 ± 0.007	0.987 ± 0.006	13.19 ± 2.1	0.88 ± 0.01	0.801 ± 0.019
Male	all patients	RCRI	0.05 ± 0.01	0.019 ± 0.002	0.987 ± 0.000	5.44 ± 0.7	0.95 ± 0.01	0.705 ± 0.020
Male	all patients	CCoR	0.12 ± 0.05	0.042 ± 0.001	0.987 ± 0.006	12.44 ± 0.3	0.89 ± 0.05	0.802 ± 0.018
Female	frail***	RCRI	0.03 ± 0.00	0.009 ± 0.002	0.987 ± 0.006	2.59 ± 0.6	0.98 ± 0.00	0.670 ± 0.028
Female	frail	CCoR	0.11 ± 0.03	0.036 ± 0.002	0.987 ± 0.000	10.36 ± 0.7	0.90 ± 0.03	0.791 ± 0.025
Male	frail	RCRI	0.06 ± 0.04	0.020 ± 0.002	0.987 ± 0.006	5.91 ± 0.7	0.95 ± 0.04	0.727 ± 0.027
Male	frail	CCoR	0.15 ± 0.03	0.050 ± 0.002	0.987 ± 0.000	15.02 ± 0.7	0.86 ± 0.03	0.810 ± 0.024
Female	high risk****	RCRI	0.02 ± 0.00	0.008 ± 0.001	0.987 ± 0.006	2.19 ± 0.3	0.99 ± 0.00	0.581 ± 0.029
Female	high risk	CCoR	0.07 ± 0.03	0.026 ± 0.002	0.987 ± 0.000	7.73 ± 0.6	0.94 ± 0.03	0.737 ± 0.026
Male	high risk	RCRI	0.03 ± 0.01	0.010 ± 0.001	0.987 ± 0.006	2.91 ± 0.3	0.98 ± 0.00	0.617 ± 0.026
Male	high risk	CCoR	0.09 ± 0.05	0.033 ± 0.002	0.987 ± 0.006	9.61 ± 0.7	0.92 ± 0.05	0.729 ± 0.024
Female	low risk†	CCoR	0.22 ± 0.04	0.071 ± 0.004	0.987 ± 0.000	21.81 ± 1.3	0.79 ± 0.04	0.765 ± 0.036
Male	low risk	CCoR	0.11 ± 0.04	0.042 ± 0.003	0.987 ± 0.000	5.96 ± 0.9	0.90 ± 0.04	0.766 ± 0.032

Abbreviations, AUC, area under the receiver operating characteristic curve; CCoR, Cardiac Co-Morbidity Risk Score; LR+, positive likelihood ratio; LR-, negative likelihood ratio; NPV, negative predictive value; PPV, positive predictive value; acc, accuracy; RCRI, Revised Cardiac Risk Index

*50% (n=445391) of cohort used for validation

**Because of insufficient availability of relevant laboratory data in the Truven dataset, presence of at least one diagnostic code for chronic kidney disease stage III or higher in the medical record in the year before the date of arthroplasty was used as a surrogate for the RCRI condition, serum creatinine concentration $>$ 2.0mg/dL (to convert to micromoles per liter, multiply by 88.4).

***Frail subcategory was defined by codes specified in Table S7

****Low risk subcohort comprises patients with RCRI score 0. High risk patients have RCRI score > 0.

†No RCRI performance logged for low-risk patients, since their RCRI score is zero.

Table S15: Out-of-sample* performance for predicting MACE with 2 weeks of Hip or Knee Arthroplasty (Secondary Endpoint) at 99% Specificity: CCoR vs. RCRI**

sex	cohort	model	sensitivity	PPV	acc	LR+	LR-	AUC
Female	<65	RCRI	0.01 ± 0.02	0.009 ± 0.000	0.987 ± 0.006	0.04 ± 0.1	1.00 ± 0.02	0.647 ± 0.044
Female	<65	CCoR	0.11 ± 0.01	0.073 ± 0.023	0.987 ± 0.006	22.87 ± 8.5	0.90 ± 0.01	0.787 ± 0.039
Male	<65	RCRI	0.09 ± 0.02	0.032 ± 0.009	0.987 ± 0.000	9.33 ± 2.8	0.92 ± 0.02	0.688 ± 0.037
Male	<65	CCoR	0.14 ± 0.04	0.056 ± 0.004	0.987 ± 0.000	16.83 ± 1.3	0.87 ± 0.04	0.797 ± 0.033
Female	65+	RCRI	0.04 ± 0.04	0.013 ± 0.002	0.987 ± 0.006	3.66 ± 0.6	0.97 ± 0.03	0.671 ± 0.030
Female	65+	CCoR	0.10 ± 0.03	0.041 ± 0.002	0.987 ± 0.000	12.08 ± 0.7	0.91 ± 0.04	0.787 ± 0.027
Male	65+	RCRI	0.03 ± 0.00	0.010 ± 0.001	0.987 ± 0.000	2.79 ± 0.4	0.98 ± 0.00	0.667 ± 0.028
Male	65+	CCoR	0.09 ± 0.03	0.032 ± 0.002	0.987 ± 0.000	9.32 ± 0.6	0.92 ± 0.03	0.780 ± 0.025
Female	all patients	RCRI	0.05 ± 0.01	0.018 ± 0.003	0.987 ± 0.000	5.17 ± 0.9	0.96 ± 0.01	0.692 ± 0.025
Female	all patients	CCoR	0.14 ± 0.06	0.048 ± 0.001	0.987 ± 0.006	14.48 ± 0.3	0.87 ± 0.06	0.809 ± 0.021
Male	all patients	RCRI	0.05 ± 0.01	0.018 ± 0.002	0.987 ± 0.000	5.15 ± 0.7	0.96 ± 0.01	0.710 ± 0.022
Male	all patients	CCoR	0.14 ± 0.02	0.047 ± 0.007	0.987 ± 0.000	13.98 ± 2.1	0.87 ± 0.02	0.813 ± 0.019
Female	frail***	RCRI	0.03 ± 0.01	0.012 ± 0.003	0.987 ± 0.000	3.43 ± 0.9	0.98 ± 0.01	0.676 ± 0.032
Female	frail	CCoR	0.12 ± 0.03	0.041 ± 0.009	0.987 ± 0.000	11.78 ± 2.7	0.89 ± 0.03	0.807 ± 0.027
Male	frail	RCRI	0.06 ± 0.01	0.020 ± 0.003	0.987 ± 0.000	5.82 ± 0.9	0.95 ± 0.01	0.736 ± 0.029
Male	frail	CCoR	0.17 ± 0.03	0.059 ± 0.009	0.987 ± 0.000	17.76 ± 3.0	0.84 ± 0.03	0.825 ± 0.025
Female	high risk****	RCRI	0.02 ± 0.03	0.008 ± 0.001	0.987 ± 0.006	2.35 ± 0.4	0.99 ± 0.02	0.584 ± 0.032
Female	high risk	CCoR	0.08 ± 0.00	0.029 ± 0.006	0.987 ± 0.006	8.45 ± 1.9	0.93 ± 0.01	0.742 ± 0.028
Male	high risk	RCRI	0.03 ± 0.03	0.009 ± 0.001	0.987 ± 0.006	2.69 ± 0.4	0.98 ± 0.02	0.628 ± 0.028
Male	high risk	CCoR	0.09 ± 0.02	0.033 ± 0.007	0.987 ± 0.000	9.66 ± 2.3	0.92 ± 0.02	0.737 ± 0.026
Female	low risk†	CCoR	0.28 ± 0.07	0.092 ± 0.002	0.988 ± 0.006	28.78 ± 0.7	0.72 ± 0.07	0.779 ± 0.040
Male	low risk	CCoR	0.12 ± 0.04	0.047 ± 0.004	0.987 ± 0.000	6.78 ± 1.1	0.89 ± 0.05	0.793 ± 0.035

Abbreviations, AUC, area under the receiver operating characteristic curve; CCoR, Cardiac Co-Morbidity Risk Score; LR+, positive likelihood ratio; LR-, negative likelihood ratio; NPV, negative predictive value; PPV, positive predictive value; acc, accuracy; RCRI, Revised Cardiac Risk Index

*50% (n=445391) of cohort used for validation

**Because of insufficient availability of relevant laboratory data in the Truven dataset, presence of at least one diagnostic code for chronic kidney disease stage III or higher in the medical record in the year before the date of arthroplasty was used as a surrogate for the RCRI condition, serum creatinine concentration > 2.0mg/dL (to convert to micromoles per liter, multiply by 88.4).

***Frail subcategory was defined by codes specified in Table S7

****Low risk subcohort comprises patients with RCRI score 0. High risk patients have RCRI score > 0.

†No RCRI performance logged for low-risk patients, since their RCRI score is zero.

Table S16: Statistical significance of CCoR AUC $>$ RCRI AUC ($\star$ denotes signifance at 95% level, $\star\star$ denotes significance at 99% level)

sex	model	weeks after surgery	RCRI auc	CCoR auc	p value	significance
Female	all patients	2	0.692	0.809	0.010	**
		4	0.688	0.801	0.007	**
	frail†	2	0.676	0.807	0.017	*
		4	0.670	0.791	0.014	*
	high risk‡	2	0.584	0.742	0.005	**
		4	0.581	0.737	0.003	**
	65+	2	0.671	0.787	0.020	*
		4	0.664	0.771	0.020	*
	$<$ 65	2	0.647	0.787	0.036	*
		4	0.639	0.775	0.028	*
Male	all patients	2	0.710	0.813	0.010	*
		4	0.705	0.802	0.009	**
	frail	2	0.736	0.825	0.045	*
		4	0.727	0.810	0.042	*
	high risk	2	0.628	0.737	0.017	*
		4	0.617	0.729	0.011	*
	65+	2	0.667	0.780	0.017	*
		4	0.661	0.762	0.019	*
	$<$ 65	2	0.688	0.797	0.047	*
		4	0.682	0.783	0.042	*

†Frail subcategory was defined by codes specified in Table S7

‡Low risk subcohort comprises patients with RCRI score 0. High risk patients have RCRI score $>$ 0.

Table S17: Out-of-sample performance achieved using only PFSA component of the CCoR model (Note: the performance is significantly degraded, with all p-values $<$ 0.01.)

sex	prediction horizon	AUC
Female	2 weeks	0.696 ± 0.082
Female	4 weeks	0.698 ± 0.074
Male	2 weeks	0.679 ± 0.074
Male	4 weeks	0.656 ± 0.067

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