## I. SUPPLEMENTARY MATERIAL

## A. Acute Kidney Injury (AKI)

- 1) Overall Performance: SHAP Filter vs. SHAP Weight: Table I summarizes the overall 5-fold cross-validation performance for the baseline SHAP-based filtering and weighting strategies. Results show that SHAP weighting consistently achieves higher AUC, F1, and recall across all models compared to SHAP filtering.
- 2) SHAP Filter Variants: Table II reports the 5-fold cross-validation performance for each SHAP Filter variant, including combinations with Isolation Forest (IF), Odds Ratio (OR), or both. These variants illustrate the limitations of unweighted filtering, particularly in models' precision–recall trade-offs.
- *3)* SHAP Weight Variants: Table III presents the 5-fold cross-validation performance for each SHAP Weight variant. Weighting schemes consistently improve model robustness, with the IF + OR combination yielding the best overall scores across most metrics.

TABLE I
5-FOLD CV RESULTS FOR SHAP FILTER VS. SHAP WEIGHT BASELINES (MEAN ± STD).

Strategy	Model	AUC	Accuracy	F1 Score	Precision	Recall
SHAP Filter (Baseline)	Logistic MLP RF XGB	$0.8748 \pm 0.0140$ $0.8532 \pm 0.0228$ $0.8610 \pm 0.0190$ $0.8072 \pm 0.0383$	$0.7962 \pm 0.0248$ $0.7857 \pm 0.0358$ $0.7850 \pm 0.0307$ $0.7530 \pm 0.0354$	$0.6021 \pm 0.0964$ $0.5793 \pm 0.1414$ $0.5658 \pm 0.1389$ $0.5533 \pm 0.0611$	0.7968 ± 0.0348 0.7571 ± 0.0118 0.7933 ± 0.0681 0.6878 ± 0.1217	0.4966 ± 0.1215 0.4877 ± 0.1593 0.4708 ± 0.1847 0.4861 ± 0.1200
SHAP Weight	Logistic MLP RF XGB	$0.9154 \pm 0.0006$ $0.9209 \pm 0.0006$ $0.9226 \pm 0.0008$ $0.9361 \pm 0.0005$	0.8340 ± 0.0022 0.8421 ± 0.0028 0.8535 ± 0.0009 0.8568 ± 0.0018	0.7613 ± 0.0008 0.7677 ± 0.0008 0.7545 ± 0.0018 0.7906 ± 0.0021	$0.7069 \pm 0.0075$ $0.7274 \pm 0.0101$ $0.8163 \pm 0.0038$ $0.7450 \pm 0.0049$	$0.8251 \pm 0.0095$ $0.8131 \pm 0.0113$ $0.7013 \pm 0.0046$ $0.8423 \pm 0.0060$

Strategy	Model	AUC	Accuracy	F1 Score	Precision	Recall
Baseline - SHAP Filter	Logistic	$0.8748 \pm 0.0140$	$0.7962 \pm 0.0248$	$0.6021 \pm 0.0964$	$0.7968 \pm 0.0348$	$0.4966 \pm 0.1215$
	MLP	$0.8532 \pm 0.0228$	$0.7857 \pm 0.0358$	$0.5793 \pm 0.1414$	$0.7571 \pm 0.0118$	$0.4877 \pm 0.1593$
	RF	$0.8610 \pm 0.0190$	$0.7850 \pm 0.0307$	$0.5658 \pm 0.1389$	$0.7933 \pm 0.0681$	$0.4708 \pm 0.1847$
	XGB	$0.8072 \pm 0.0383$	$0.7530 \pm 0.0354$	$0.5533 \pm 0.0611$	$0.6878 \pm 0.1217$	$0.4861 \pm 0.1200$
IF only - SHAP Filter	Logistic	$0.8703 \pm 0.0202$	$0.7592 \pm 0.0555$	$0.4407 \pm 0.3033$	$0.8013 \pm 0.1156$	$0.3909 \pm 0.3155$
	MLP	$0.8464 \pm 0.0458$	$0.7605 \pm 0.0512$	$0.4521 \pm 0.2761$	$0.7937 \pm 0.1120$	$0.3887 \pm 0.2859$
	RF	$0.8429 \pm 0.0185$	$0.7571 \pm 0.0437$	$0.4379 \pm 0.2283$	$0.8226 \pm 0.0943$	$0.3529 \pm 0.2521$
	XGB	$0.7611 \pm 0.0534$	$0.7312 \pm 0.0431$	$0.3933 \pm 0.2362$	$0.7041 \pm 0.0967$	$0.3245 \pm 0.2305$
OR only - SHAP Filter	Logistic	$0.8684 \pm 0.0101$	$0.7643 \pm 0.0263$	$0.4566 \pm 0.1200$	$0.8640 \pm 0.0543$	$0.3243 \pm 0.1310$
	MLP	$0.8312 \pm 0.0456$	$0.7398 \pm 0.0542$	$0.3300 \pm 0.2898$	$0.8692 \pm 0.1039$	$0.2571 \pm 0.2560$
	RF	$0.8303 \pm 0.0308$	$0.7518 \pm 0.0255$	$0.4165 \pm 0.1274$	$0.8364 \pm 0.0602$	$0.2907 \pm 0.1243$
	XGB	$0.7591 \pm 0.1048$	$0.7473 \pm 0.0435$	$0.4616 \pm 0.1624$	$0.7033 \pm 0.1174$	$0.3633 \pm 0.1729$
IF + Odds - SHAP Filter	Logistic	$0.8717 \pm 0.0237$	$0.7794 \pm 0.0481$	$0.5531 \pm 0.2246$	$0.7805 \pm 0.1273$	$0.4975 \pm 0.2539$
	MLP	$0.8608 \pm 0.0210$	$0.7737 \pm 0.0542$	$0.5312 \pm 0.2918$	$0.7605 \pm 0.1154$	$0.5056 \pm 0.3033$
	RF	$0.8735 \pm 0.0100$	$0.7837 \pm 0.0417$	$0.5468 \pm 0.2052$	$0.8132 \pm 0.0990$	$0.4642 \pm 0.2289$
	XGB	$0.8146 \pm 0.0488$	$0.7584 \pm 0.0446$	$0.4953 \pm 0.2676$	$0.7266 \pm 0.0816$	$0.4491 \pm 0.2600$

Strategy	Model	AUC	Accuracy	F1 Score	Precision	Recall
Shapley Weight	Logistic	$0.9154 \pm 0.0006$	0.8340 ± 0.0022	0.7613 ± 0.0008	$0.7069 \pm 0.0075$	$0.8251 \pm 0.0095$
	MLP	$0.9209 \pm 0.0006$	0.8421 ± 0.0028	0.7677 ± 0.0008	$0.7274 \pm 0.0101$	$0.8131 \pm 0.0113$
	RF	$0.9226 \pm 0.0008$	0.8535 ± 0.0009	0.7545 ± 0.0018	$0.8163 \pm 0.0038$	$0.7013 \pm 0.0046$
	XGB	$0.9361 \pm 0.0005$	0.8568 ± 0.0018	0.7906 ± 0.0021	$0.7450 \pm 0.0049$	$0.8423 \pm 0.0060$
IF only - SHAP Weight	Logistic	$0.9155 \pm 0.0006$	$0.8317 \pm 0.0030$	$0.7607 \pm 0.0012$	$0.6997 \pm 0.0087$	$0.8337 \pm 0.0104$
	MLP	$0.9211 \pm 0.0011$	$0.8319 \pm 0.0059$	$0.7639 \pm 0.0025$	$0.6960 \pm 0.0182$	$0.8475 \pm 0.0217$
	RF	$0.9225 \pm 0.0009$	$0.8535 \pm 0.0006$	$0.7540 \pm 0.0019$	$0.8174 \pm 0.0014$	$0.6998 \pm 0.0042$
	XGB	$0.9362 \pm 0.0006$	$0.8548 \pm 0.0029$	$0.7895 \pm 0.0022$	$0.7381 \pm 0.0083$	$0.8489 \pm 0.0060$
OR only - SHAP Weight	Logistic	0.9154 ± 0.0006	0.8342 ± 0.0014	0.7612 ± 0.0007	$0.7078 \pm 0.0059$	$0.8234 \pm 0.0089$
	MLP	0.9208 ± 0.0005	0.8347 ± 0.0087	0.7649 ± 0.0042	$0.7051 \pm 0.0243$	$0.8373 \pm 0.0246$
	RF	0.9226 ± 0.0010	0.8533 ± 0.0004	0.7542 ± 0.0011	$0.8155 \pm 0.0018$	$0.7015 \pm 0.0029$
	XGB	0.9361 ± 0.0006	0.8560 ± 0.0024	0.7895 ± 0.0018	$0.7438 \pm 0.0080$	$0.8414 \pm 0.0075$
IF + Odds - SHAP Weight	Logistic	$0.9155 \pm 0.0006$	$0.8332 \pm 0.0014$	0.7613 ± 0.0009	0.7041 ± 0.0039	$0.8286 \pm 0.0038$
	MLP	$0.9211 \pm 0.0010$	$0.8370 \pm 0.0041$	0.7660 ± 0.0015	0.7108 ± 0.0154	$0.8313 \pm 0.0199$
	RF	$0.9221 \pm 0.0008$	$0.8528 \pm 0.0004$	0.7533 ± 0.0015	0.8150 ± 0.0019	$0.7003 \pm 0.0038$
	XGB	$0.9360 \pm 0.0005$	$0.8559 \pm 0.0017$	0.7901 ± 0.0014	0.7416 ± 0.0047	$0.8455 \pm 0.0037$

## B. Full Performance Overview: Diabetes Mellitus (ICD - 250)

Table IV presents the 5-fold CV results for the SHAP Filter and SHAP Weight strategies applied to diabetes mellitus prediction. The observed performance gains further support the generalizability of our refinement framework.

 $\label{thm:table_iv} \mbox{TABLE IV} \\ \mbox{5-fold CV Results on ICD-250 for All SHAP-based Refinement Strategies (Mean <math>\pm$  Std).}

Strategy	Model	AUC	Accuracy	F1 Score	Precision	Recall
Baseline - SHAP Filter	Logistic	$0.6487 \pm 0.0720$	0.7600 ± 0.0369	0.2795 ± 0.1028	0.3973 ± 0.1211	0.2328 ± 0.1125
	MLP	$0.5952 \pm 0.0941$	$0.7644 \pm 0.0355$	$0.1799 \pm 0.0779$	$0.3769 \pm 0.1291$	$0.1306 \pm 0.0735$
Baselille - SHAF Filler	RF	$0.7448 \pm 0.0921$	$0.7982 \pm 0.0226$	$0.1282 \pm 0.1589$	$0.7910 \pm 0.2604$	$0.0803 \pm 0.1043$
	XGB	$0.6009 \pm 0.1228$	$0.7662 \pm 0.0560$	$0.0427 \pm 0.0795$	$0.3989 \pm 0.4666$	$0.0390 \pm 0.0790$
	Logistic	$0.9010 \pm 0.0008$	$0.8764 \pm 0.0084$	$0.7036 \pm 0.0053$	$0.7099 \pm 0.0370$	$0.7000 \pm 0.0320$
Baseline - SHAP Weight	MLP	$0.9195 \pm 0.0023$	$0.8827 \pm 0.0171$	$0.7286 \pm 0.0183$	$0.7197 \pm 0.0783$	$0.7496 \pm 0.0672$
Baseline - STIAI Weight	RF	$0.9203 \pm 0.0024$	$0.9014 \pm 0.0020$	$0.7276 \pm 0.0076$	$0.8627 \pm 0.0032$	$0.6291 \pm 0.0118$
	XGB	$0.9264 \pm 0.0015$	$0.8967 \pm 0.0039$	$0.7524 \pm 0.0044$	$0.7560 \pm 0.0197$	$0.7494 \pm 0.0147$
	Logistic	$0.6494 \pm 0.0705$	$0.6802 \pm 0.1287$	$0.3691 \pm 0.0215$	$0.3709 \pm 0.1343$	$0.4440 \pm 0.1616$
IF + Odds - SHAP Filter	MLP	$0.6436 \pm 0.0425$	$0.7073 \pm 0.0896$	$0.3137 \pm 0.0584$	$0.3835 \pm 0.1503$	$0.3411 \pm 0.1782$
n + Odds - Shar Ther	RF	$0.6948 \pm 0.0550$	$0.7811 \pm 0.0256$	$0.1602 \pm 0.1778$	$0.6387 \pm 0.3111$	$0.1328 \pm 0.1774$
	XGB	$0.5747 \pm 0.0670$	$0.7753 \pm 0.0226$	$0.1565 \pm 0.2249$	$0.2568 \pm 0.2233$	$0.1510 \pm 0.2361$
	Logistic	$0.9032 \pm 0.0007$	$0.8811 \pm 0.0033$	$0.7115 \pm 0.0022$	$0.7240 \pm 0.0176$	$0.6999 \pm 0.0144$
IF + Odds - SHAP Weight	MLP	$0.9202 \pm 0.0011$	$0.8913 \pm 0.0041$	$0.7429 \pm 0.0048$	$0.7364 \pm 0.0195$	$0.7499 \pm 0.0114$
II + Ouds - SHAI Weight	RF	$0.9218 \pm 0.0012$	$0.9025 \pm 0.0003$	$0.7312 \pm 0.0020$	$0.8649 \pm 0.0053$	$0.6334 \pm 0.0056$
	XGB	$0.9274 \pm 0.0011$	$0.8980 \pm 0.0016$	$0.7539 \pm 0.0019$	$0.7624 \pm 0.0086$	$0.7456 \pm 0.0054$
	Logistic	$0.6486 \pm 0.0747$	$0.7067 \pm 0.0582$	$0.3715 \pm 0.0647$	$0.3528 \pm 0.0891$	0.4161 ± 0.1186
IF only - SHAP Filter	MLP	$0.6148 \pm 0.0997$	$0.7483 \pm 0.0377$	$0.2523 \pm 0.2015$	$0.3313 \pm 0.0905$	$0.2714 \pm 0.2596$
ir only - Shar Ther	RF	$0.6935 \pm 0.0824$	$0.7920 \pm 0.0122$	$0.1919 \pm 0.1219$	$0.5611 \pm 0.2046$	$0.1291 \pm 0.0956$
	XGB	$0.6673 \pm 0.1333$	$0.7807 \pm 0.0125$	$0.1874 \pm 0.2260$	$0.3305 \pm 0.2248$	$0.1718 \pm 0.2273$
	Logistic	$0.9019 \pm 0.0015$	$0.8811 \pm 0.0027$	$0.7088 \pm 0.0031$	$0.7278 \pm 0.0154$	$0.6911 \pm 0.0128$
IF only - SHAP Weight	MLP	$0.9180 \pm 0.0045$	$0.8909 \pm 0.0102$	$0.7364 \pm 0.0114$	$0.7502 \pm 0.0495$	$0.7266 \pm 0.0370$
ii omy - Shai weight	RF	$0.9196 \pm 0.0019$	$0.9014 \pm 0.0019$	$0.7275 \pm 0.0070$	$0.8636 \pm 0.0007$	$0.6286 \pm 0.0103$
	XGB	$0.9260 \pm 0.0028$	$0.8985 \pm 0.0026$	$0.7534 \pm 0.0052$	$0.7671 \pm 0.0103$	$0.7403 \pm 0.0069$
	Logistic	$0.5853 \pm 0.1075$	$0.7421 \pm 0.0289$	$0.2134 \pm 0.1399$	$0.3000 \pm 0.0639$	$0.1968 \pm 0.1711$
OR only - SHAP Filter	MLP	$0.5576 \pm 0.1402$	$0.7629 \pm 0.0201$	$0.1644 \pm 0.1436$	$0.2884 \pm 0.0748$	$0.1340 \pm 0.1305$
	RF	$0.7180 \pm 0.0590$	$0.7928 \pm 0.0026$	$0.1884 \pm 0.2200$	$0.3846 \pm 0.2566$	$0.1497 \pm 0.1782$
	XGB	$0.6000 \pm 0.1290$	$0.8009 \pm 0.0475$	$0.2360 \pm 0.3111$	$0.2715 \pm 0.3447$	$0.2100 \pm 0.2850$
	Logistic	$0.9010 \pm 0.0009$	$0.8791 \pm 0.0061$	$0.7048 \pm 0.0044$	$0.7228 \pm 0.0305$	$0.6891 \pm 0.0212$
OR only - SHAP Weight	MLP	$0.9192 \pm 0.0006$	$0.8905 \pm 0.0026$	$0.7409 \pm 0.0053$	$0.7349 \pm 0.0136$	$0.7475 \pm 0.0170$
or only on in weight	RF	$0.9201 \pm 0.0018$	$0.9016 \pm 0.0020$	$0.7272 \pm 0.0081$	$0.8664 \pm 0.0029$	$0.6267 \pm 0.0130$
	XGB	$0.9258 \pm 0.0021$	$0.8981 \pm 0.0034$	$0.7539 \pm 0.0045$	$0.7632 \pm 0.0159$	$0.7451 \pm 0.0066$

## C. Full Performance Overview: Heart Failure (ICD - 428)

Table V summarizes the 5-fold CV results for the SHAP Filter and SHAP Weight strategies on heart failure prediction. Similar trends to AKI are observed, with SHAP Weight consistently improving both ROC-AUC and recall across all models.

 $\label{table v} \textbf{TABLE V} \\ \textbf{5-fold CV Results on ICD-428 (Heart Failure) for All SHAP-based Refinement Strategies (Mean <math>\pm$  Std).}

Strategy	Model	AUC	Accuracy	F1 Score	Precision	Recall
Baseline - SHAP Filter	Logistic	0.7558 ± 0.1115	$0.8335 \pm 0.0396$	$0.4208 \pm 0.1413$	0.4181 ± 0.1446	$0.4264 \pm 0.1477$
	MLP	$0.7486 \pm 0.0932$	$0.8446 \pm 0.0242$	$0.3524 \pm 0.1828$	$0.4116 \pm 0.1451$	$0.3287 \pm 0.2113$
Basenne - SHAF Filter	RF	$0.7924 \pm 0.0899$	$0.8641 \pm 0.0078$	$0.2695 \pm 0.1481$	$0.5522 \pm 0.1024$	$0.1937 \pm 0.1389$
	XGB	$0.6629 \pm 0.1094$	$0.8566 \pm 0.0028$	$0.0455 \pm 0.0399$	$0.4250 \pm 0.2012$	$0.0248 \pm 0.0223$
	Logistic	$0.5997 \pm 0.2342$	$0.8325 \pm 0.0652$	$0.2127 \pm 0.2664$	$0.3269 \pm 0.3305$	0.1667 ± 0.2149
IF - SHAP Filter	MLP	$0.5559 \pm 0.2403$	$0.8545 \pm 0.0222$	$0.1286 \pm 0.1935$	$0.3218 \pm 0.3470$	$0.0842 \pm 0.1298$
II - SHAI THEI	RF	$0.7435 \pm 0.0679$	$0.8578 \pm 0.0002$	$0.1150 \pm 0.1918$	$0.3343 \pm 0.2896$	$0.0857 \pm 0.1447$
	XGB	$0.5858 \pm 0.1485$	$0.8551 \pm 0.0044$	$0.0401 \pm 0.0695$	$0.1216 \pm 0.2105$	$0.0240 \pm 0.0416$
	Logistic	$0.9178 \pm 0.0024$	$0.8945 \pm 0.0015$	$0.6453 \pm 0.0049$	$0.6194 \pm 0.0107$	$0.6741 \pm 0.0223$
IF - SHAP Weight	MLP	$0.9243 \pm 0.0011$	$0.8997 \pm 0.0065$	$0.6606 \pm 0.0084$	$0.6405 \pm 0.0390$	$0.6864 \pm 0.0524$
ii - SiiAi weight	RF	$0.9244 \pm 0.0012$	$0.9105 \pm 0.0007$	$0.6099 \pm 0.0034$	$0.8033 \pm 0.0036$	$0.4916 \pm 0.0031$
	XGB	$0.9293 \pm 0.0015$	$0.9036 \pm 0.0011$	$0.6711 \pm 0.0045$	$0.6525 \pm 0.0087$	$0.6910 \pm 0.0169$
	Logistic	$0.7964 \pm 0.0324$	$0.8397 \pm 0.0368$	$0.3895 \pm 0.0949$	$0.4749 \pm 0.1405$	$0.3770 \pm 0.1650$
IF + Odds - SHAP Filter	MLP	$0.6988 \pm 0.1635$	$0.8343 \pm 0.0319$	$0.3039 \pm 0.1791$	$0.3769 \pm 0.2065$	$0.2963 \pm 0.2118$
Ir + Odds - SHAF Filter	RF	$0.7899 \pm 0.0718$	$0.8472 \pm 0.0241$	$0.1407 \pm 0.1283$	$0.5359 \pm 0.2091$	$0.1071 \pm 0.1126$
	XGB	$0.5595 \pm 0.0818$	$0.8049 \pm 0.0839$	$0.1202 \pm 0.1650$	$0.0989 \pm 0.1365$	$0.1687 \pm 0.2472$
	Logistic	0.9200 ± 0.0025	0.8990 ± 0.0031	0.6471 ± 0.0080	0.6458 ± 0.0266	$0.6509 \pm 0.0371$
IF + Odds - SHAP Weight	MLP	$0.9258 \pm 0.0021$	$0.9015 \pm 0.0053$	$0.6636 \pm 0.0062$	$0.6483 \pm 0.0329$	$0.6827 \pm 0.0365$
II + Odds - SHAI Weight	RF	$0.9252 \pm 0.0020$	$0.9111 \pm 0.0009$	$0.6139 \pm 0.0048$	$0.8038 \pm 0.0050$	$0.4965 \pm 0.0051$
	XGB	$0.9300 \pm 0.0019$	$0.9058 \pm 0.0023$	$0.6701 \pm 0.0065$	$0.6697 \pm 0.0222$	$0.6723 \pm 0.0313$
	Logistic	$0.8236 \pm 0.0187$	$0.8457 \pm 0.0477$	$0.5156 \pm 0.0469$	$0.5035 \pm 0.1159$	$0.5650 \pm 0.1059$
Odds - SHAP Filter	MLP	$0.7865 \pm 0.0396$	$0.8440 \pm 0.0504$	$0.4641 \pm 0.0800$	$0.4997 \pm 0.1238$	$0.4774 \pm 0.1552$
Odds - SHAL THE	RF	$0.8228 \pm 0.0277$	$0.8387 \pm 0.0601$	$0.2924 \pm 0.1693$	$0.5699 \pm 0.1694$	$0.2943 \pm 0.2707$
	XGB	$0.6507 \pm 0.1055$	$0.7808 \pm 0.1213$	$0.1785 \pm 0.1302$	$0.2732 \pm 0.1923$	$0.2382 \pm 0.2725$
	Logistic	$0.9202 \pm 0.0023$	$0.8987 \pm 0.0017$	$0.6503 \pm 0.0058$	$0.6399 \pm 0.0136$	$0.6620 \pm 0.0263$
Odds - SHAP Weight	MLP	$0.9253 \pm 0.0020$	$0.8951 \pm 0.0115$	$0.6586 \pm 0.0087$	$0.6202 \pm 0.0465$	$0.7089 \pm 0.0546$
Odds - SHAF Weight	RF	$0.9254 \pm 0.0021$	$0.9111 \pm 0.0007$	$0.6135 \pm 0.0043$	$0.8050 \pm 0.0049$	$0.4956 \pm 0.0058$
	XGB	$0.9299 \pm 0.0016$	$0.9048 \pm 0.0021$	$0.6717 \pm 0.0054$	$0.6601 \pm 0.0132$	$0.6844 \pm 0.0200$
	Logistic	$0.9204 \pm 0.0025$	$0.9020 \pm 0.0025$	$0.6480 \pm 0.0073$	$0.6636 \pm 0.0169$	$0.6337 \pm 0.0201$
Shapley - SHAP Weight	MLP	$0.9249 \pm 0.0021$	$0.9017 \pm 0.0071$	$0.6582 \pm 0.0060$	$0.6584 \pm 0.0558$	$0.6650 \pm 0.0562$
Shapley Sill in mergin	RF	$0.9251 \pm 0.0015$	$0.9112 \pm 0.0011$	$0.6159 \pm 0.0096$	$0.8014 \pm 0.0042$	$0.5003 \pm 0.0141$
	XGB	$0.9299 \pm 0.0028$	$0.9078 \pm 0.0023$	$0.6711 \pm 0.0045$	$0.6822 \pm 0.0160$	$0.6608 \pm 0.0153$