



Figure E1. (a–c) Probability histograms. The positive class (class of interest) is plotted in red, and the negative class is plotted in blue. The vertical black line indicates the probability threshold corresponding to 90% sensitivity. (a) TTB probability histogram. (b) TIPS probability histogram. (c) UAE probability histogram.

Table E1. Features Used as Inputs into TTB Random Forest Model

913	Age at admission, y
914	Admission day is on a weekend
915	Elective vs nonelective admission
916	Indicator of sex
917	HCUP indicator of emergency department record
918	Census Division of hospital (strata)
919	ICD-9-CM number of chronic conditions
920	Expected primary payer, uniform
921	Patient location: NCHS urban-rural code
922	Recorded BMI > 30
923	Race
924	Service line based on ICD-9 codes
925	Indicator of transfer into the hospital
926	Median household income for patient's ZIP Code
927	H/O Administrative/social admission
928	H/O Allergic reactions
929	H/O Bacterial infection, unspecified site
930	H/O Calculus of urinary tract
931	H/O Cancer of bladder
932	H/O Cancer of brain and nervous system
933	H/O Cancer of breast
934	H/O Cancer of bronchus, lung
935	H/O Cancer of cervix
936	H/O Cancer of colon
937	H/O Cancer of esophagus
938	H/O Cancer of head and neck
939	H/O Cancer of kidney and renal pelvis
940	H/O Cancer of liver and intrahepatic bile duct
941	H/O Cancer of other gastrointestinal organs, peritoneum
942	H/O Cancer of other female genital organs
943	H/O Cancer of other male genital organs
944	H/O Cancer of other urinary organs
945	H/O Cancer of ovary
946	H/O Cancer of prostate
947	H/O Cancer of rectum and anus
948	H/O Cancer of stomach
949	H/O Cancer of testis
950	H/O Cancer of thyroid
951	H/O Cancer of uterus
952	H/O Cancer, other and unspecified primary
953	H/O Cancer, other respiratory and intrathoracic
954	H/O Cardiac and circulatory congenital anomalies
955	H/O Cataract
956	H/O Chronic kidney disease
957	H/O Complications of surgical procedures or medical care
958	H/O Conduction disorders
959	H/O Contraceptive and procreative management
960	H/O Coronary atherosclerosis and other heart disease
961	H/O Diabetes mellitus without complication
962	H/O Fracture of neck of femur (hip)
963	H/O Fracture of upper limb
964	H/O Gastroduodenal ulcer (except hemorrhage)
965	H/O Genitourinary symptoms and ill-defined conditions

*continued***Table E1.** Features Used as Inputs into TTB Random Forest Model (*continued*)

970	H/O HIV infection	970
971	H/O Heart valve disorders	971
972	H/O Hodgkin disease	972
973	H/O Immunizations and screening for infectious disease	973
974	H/O Intracranial injury	974
975	H/O Leukemias	975
976	H/O Maintenance chemotherapy, radiotherapy	976
977	H/O Medical examination/evaluation	977
978	H/O Melanomas of skin	978
979	H/O Menopausal disorders	979
980	H/O Miscellaneous mental health disorders	980
981	H/O Non-Hodgkin lymphoma	981
982	H/O Osteoarthritis	982
983	H/O Other CNS infection and poliomyelitis	983
984	H/O Other aftercare	984
985	H/O Other and unspecified benign neoplasm	985
986	H/O Other circulatory disease	986
987	H/O Other congenital anomalies	987
988	H/O Other connective tissue disease	988
989	H/O Other ear and sense organ disorders	989
990	H/O Other eye disorders	990
991	H/O Other female genital disorders	991
992	H/O Other fractures	992
993	H/O Other gastrointestinal disorders	993
994	H/O Other hematologic conditions	994
995	H/O Other infections, including parasitic	995
996	H/O Other injuries and conditions due to external causes	996
997	H/O Other liver diseases	997
998	H/O Other lower respiratory disease	998
999	H/O Other nervous system disorders	999
1000	H/O Other nonepithelial cancer of skin	1000
1001	H/O Other nutritional, endocrine, and metabolic disorders	1001
1002	H/O Other screening for suspected conditions (not mental disorders or infectious disease)	1002
1003	H/O Other upper respiratory disease	1003
1004	H/O Pathologic fracture	1004
1005	H/O Phlebitis, thrombophlebitis, and thromboembolism	1005
1006	H/O Rehabilitation care, fitting of prostheses, and adjustment of devices	1006
1007	H/O Residual codes, unclassified	1007
1008	H/O Respiratory failure, insufficiency, arrest (adult)	1008
1009	H/O Screening and history of mental health and substance abuse codes	1009
1010	H/O Substance-related disorders	1010
1011	H/O Suicide and intentional self-inflicted injury	1011
1012	H/O Tuberculosis	1012

BMI = body mass index; CNS = central nervous system; HCUP = Healthcare Cost and Utilization Project; HIV = human immunodeficiency virus; H/O = history of; ICD-9-CM = *International Classification of Diseases, 9th Revision, Clinical Modification*; NCHS = National Center for Health Statistics; TTB = transthoracic biopsy.

Table E2. Features Used as Inputs into TIPS Random Forest Model

1027	Age at admission, y
1028	Admission day is on a weekend
1029	Elective vs nonelective admission
1030	Indicator of sex
1031	HCUP indicator of emergency department record
1032	Census Division of hospital (strata)
1033	ICD-9-CM number of chronic conditions
1034	Expected primary payer, uniform
1035	Patient Location: NCHS urban-rural code
1036	Recorded BMI > 30
1037	Race
1038	Service line based on ICD-9 codes
1039	Indicator of transfer into the hospital
1040	Median household income for patient's ZIP Code
1041	H/O Administrative/social admission
1042	H/O Allergic reactions
1043	H/O Bacterial infection, unspecified site
1044	H/O Calculus of urinary tract
1045	H/O Cancer of bladder
1046	H/O Cancer of breast
1047	H/O Cancer of bronchus, lung
1048	H/O Cancer of cervix
1049	H/O Cancer of colon
1050	H/O Cancer of esophagus
1051	H/O Cancer of head and neck
1052	H/O Cancer of kidney and renal pelvis
1053	H/O Cancer of liver and intrahepatic bile duct
1054	H/O Cancer of other gastrointestinal organs, peritoneum
1055	H/O Cancer of other female genital organs
1056	H/O Cancer of ovary
1057	H/O Cancer of prostate
1058	H/O Cancer of rectum and anus
1059	H/O Cancer of stomach
1060	H/O Cancer of testis
1061	H/O Cancer of thyroid
1062	H/O Cancer of uterus
1063	H/O Cancer, other and unspecified primary
1064	H/O Cardiac and circulatory congenital anomalies
1065	H/O Cataract
1066	H/O Chronic kidney disease
1067	H/O Conduction disorders
1068	H/O Contraceptive and procreative management
1069	H/O Coronary atherosclerosis and other heart disease
1070	H/O Diabetes mellitus without complication
1071	H/O Digestive congenital anomalies
1072	H/O Gastroduodenal ulcer (except hemorrhage)
1073	H/O Genitourinary symptoms and ill-defined conditions
1074	H/O HIV infection
1075	H/O Heart valve disorders
1076	H/O Immunizations and screening for infectious disease
1077	H/O Intracranial injury
1078	H/O Leukemias
1079	H/O Medical examination/evaluation

*continued***Table E2.** Features Used as Inputs into TIPS Random Forest Model (*continued*)

1084	H/O Melanomas of skin
1085	H/O Menopausal disorders
1086	H/O Non-Hodgkin lymphoma
1087	H/O Other CNS infection and poliomyelitis
1088	H/O Other aftercare
1089	H/O Other and unspecified benign neoplasm
1090	H/O Other circulatory disease
1091	H/O Other congenital anomalies
1092	H/O Other connective tissue disease
1093	H/O Other eye disorders
1094	H/O Other fractures
1095	H/O Other gastrointestinal disorders
1096	H/O Other infections, including parasitic
1097	H/O Other injuries and conditions due to external causes
1098	H/O Other liver diseases
1099	H/O Other lower respiratory disease
1100	H/O Other nervous system disorders
1101	H/O Other nonepithelial cancer of skin
1102	H/O Other nutritional, endocrine, and metabolic disorders
1103	H/O Other skin disorders
1104	H/O Other upper respiratory disease
1105	H/O Phlebitis, thrombophlebitis, and thromboembolism
1106	H/O Rehabilitation care, fitting of prostheses, and adjustment of devices
1107	H/O Residual codes, unclassified
1108	H/O Respiratory failure, insufficiency, arrest (adult)
1109	H/O Screening and history of mental health and substance abuse codes
1110	H/O Substance-related disorders
1111	H/O Suicide and intentional self-inflicted injury
1112	H/O Tuberculosis

BMI = body mass index; CNS = central nervous system; HCUP = Healthcare Cost and Utilization Project; HIV = human immunodeficiency virus; H/O = history of; ICD-9-CM = *International Classification of Diseases, 9th Revision, Clinical Modification*; NCHS = National Center for Health Statistics; TIPS = transjugular intrahepatic portosystemic shunt.

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Table E3. Features Used as Inputs into UAE Random Forest Model

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- Age at admission, y
- Admission day is on a weekend
- Elective vs nonelective admission
- Indicator of sex
- HCUP indicator of emergency department record
- Census Division of hospital (strata)
- ICD-9-CM number of chronic conditions
- Expected primary payer, uniform
- Patient location: NCHS urban-rural code
- Recorded BMI > 30
- Race
- Service line based on ICD-9 codes
- Indicator of transfer into the hospital
- Median household income for patient's ZIP Code
- H/O Administrative/social admission
- H/O Allergic reactions
- H/O Calculus of urinary tract
- H/O Cancer of breast
- H/O Cancer of cervix
- H/O Cancer of colon
- H/O Cancer of kidney and renal pelvis
- H/O Cancer of rectum and anus
- H/O Cancer of thyroid
- H/O Cardiac and circulatory congenital anomalies
- H/O Chronic kidney disease
- H/O Conduction disorders
- H/O Contraceptive and procreative management
- H/O Coronary atherosclerosis and other heart disease
- H/O Genitourinary symptoms and ill-defined conditions
- H/O HIV infection
- H/O Heart valve disorders
- H/O Hodgkin disease
- H/O Immunizations and screening for infectious disease
- H/O Medical examination/evaluation
- H/O Melanomas of skin
- H/O Menopausal disorders
- H/O Other CNS infection and poliomyelitis
- H/O Other aftercare
- H/O Other and unspecified benign neoplasm
- H/O Other circulatory disease
- H/O Other complications of birth, puerperium affecting management of mother
- H/O Other complications of pregnancy
- H/O Other connective tissue disease
- H/O Other eye disorders
- H/O Other female genital disorders
- H/O Other gastrointestinal disorders
- H/O Other hematologic conditions
- H/O Other infections, including parasitic
- H/O Other injuries and conditions due to external causes
- H/O Other lower respiratory disease
- H/O Other nervous system disorders
- H/O Other nonepithelial cancer of skin

continued

Table E3. Features Used as Inputs into UAE Random Forest Model (*continued*)

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- H/O Other nutritional, endocrine, and metabolic disorders
- H/O Other pregnancy and delivery, including normal
- H/O Phlebitis, thrombophlebitis, and thromboembolism
- H/O Residual codes, unclassified
- H/O Respiratory failure, insufficiency, arrest (adult)
- H/O Screening and history of mental health and substance abuse codes
- H/O Substance-related disorders
- H/O Suicide and intentional self-inflicted injury

BMI = body mass index; CNS = central nervous system; HCUP = Healthcare Cost and Utilization Project; HIV = human immunodeficiency virus; H/O = history of; ICD-9-CM = *International Classification of Diseases, 9th Revision, Clinical Modification*; NCHS = National Center for Health Statistics; UAE = uterine artery embolization.

Table E4. Training, Tuning, and Testing Counts

Procedure	Pre-SMOTE Training	Post-SMOTE Training	Tuning Testing	
TTB	6,023	3,864	3,011	3,012
TIPS	1,131	2,750	566	566
UAE	413	2,124	207	206

Note—Number of patients in each of the randomly partitioned subsets. The pre-SMOTE training set is provided as input to the SMOTE algorithm. The post-SMOTE training set is used to train the random forest models. The tuning set is used to hand-tune the hyperparameters. The testing set is used to evaluate the performance of the models.
SMOTE = Synthetic Minority Oversampling Technique; TIPS = transjugular intrahepatic portosystemic shunt; TTB = trans-thoracic biopsy; UAE = uterine artery embolization.