In [6]:
```python
import pandas as pd
import numpy as np
```

In [7]:
```python
data = pd.read_csv("Data4Modelling.csv")
```

In [8]:
```python
data = data.replace([np.inf, -np.inf], 0)
```

In [9]:
```python
non_numeric_columns = data.select_dtypes(exclude=[float, int])
data["weight"]  = ["UNK" if str(i) == str(np.nan) else i for i in data["weight"] ]
data.weight.value_counts()
```

Out[9]:
```
weight
UNK          96958
[75-100)      1320
[50-75)        881
[100-125)      622
[125-150)      143
[25-50)         94
[0-25)          48
[150-175)       34
[175-200)       11
>200             3
Name: count, dtype: int64
```

In [10]:
```python
weightDict = {'[50-75)' : '62',
'[75-100)' : '87',
'[100-125)' : '112',
'[125-150)' : '137',
'[25-50)' : '37',
'[0-25)' : '12',
'[150-175)' : '162',
'[175-200)' : '187',
'>200' : '200',
'UNK' : f"{np.nan}"}

data['weight'] = data['weight'].apply(lambda x : weightDict[x])
```

In [11]:
```python
data.weight = data.weight.astype(float)
```

In [12]:
```python
data_checkout = data.copy()
```

In [13]:
```python
from sklearn.preprocessing import LabelEncoder
label_encoder = LabelEncoder()
```

In [14]:
```python
for column in data.columns:
    if data[column].dtype == 'object':
        data[column] = label_encoder.fit_transform(data[column])
```

```
C:\Users\user\miniconda3\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Users\user\miniconda3\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Users\user\miniconda3\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
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C:\Users\user\miniconda3\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

In [15]:
```
data['readmitted'].value_counts()
```

Out[15]:
```
readmitted
0    88757
1    11357
Name: count, dtype: int64
```

In [16]:
```
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import StratifiedKFold, train_test_split
import time
from sklearn.metrics import classification_report, confusion_matrix, accuracy_score
from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import GradientBoostingClassifier,RandomForestClassifier, Ext
from lightgbm import LGBMClassifier
from catboost import CatBoostClassifier
from xgboost import XGBClassifier
from tabulate import tabulate
from tqdm import tqdm
```

In [17]:
```
def BasedLine(df, method, models, n_splits=10):
    start_time = time.time()  # Record the start time

    df_check = df.copy()

    df_check.weight = df_check.weight.fillna(method)

    y = df_check['readmitted']
    X = df_check.drop(columns='readmitted')

    # Define the cross-validation strategy (Stratified K-Fold)
    stratified_kfold = StratifiedKFold(n_splits=n_splits, random_state=2023, shuffl

    # Test options and evaluation metric
    scoring = 'accuracy'
    results, results_weigh = [], []
    names = []
    scores, scores_weigh = [], []
    data = []
    for name, model in models:
        # Initialize lists to store individual model scores
        model_scores = []
        model_scores_weigh = []

        with tqdm(total=n_splits, desc=f"Running {name}") as pbar:
            for train_idx, test_idx in stratified_kfold.split(X, y):
                X_train, X_valid = X.iloc[train_idx], X.iloc[test_idx]
                y_train, y_valid = y.iloc[train_idx], y.iloc[test_idx]

                model.fit(X_train, y_train)
                score_non = f1_score(model.predict(X_valid), y_valid)
                score_weigh = f1_score(model.predict(X_valid), y_valid, average='we
                model_scores.append(score_non)
                model_scores_weigh.append(score_weigh)
                pbar.update(1)

        names.append(name)
        scores_weigh.append(model_scores_weigh)

        data.append([name, np.mean(model_scores), np.mean(model_scores_weigh)])
```

```python
    print(tabulate(data, headers=["Model", "F1 Score", "F1 Score Weighted"], tablef

    end_time = time.time()  # Record the end time
    execution_time = end_time - start_time
    print("Execution time: {:.2f} seconds".format(execution_time))

    df_results = pd.DataFrame(data, columns=["Model", "F1 Score", "F1 Score Weighte
    return df_results
```

In [18]:
```python
weight_mean = data.weight.mean()
```

In [23]:
```python
def BasedModel():
    basedModels = []
    basedModels.append(('LR'    , LogisticRegression()))
    basedModels.append(('RF'    , RandomForestClassifier()))
    basedModels.append(('GBM'   , GradientBoostingClassifier()))
    basedModels.append(('ET'    , ExtraTreesClassifier()))
    basedModels.append(('XG'    , XGBClassifier()))
    basedModels.append(('LG'    , LGBMClassifier()))
    basedModels.append(('CAT'    , CatBoostClassifier(silent=True)))
    return basedModels
```

In [24]:
```python
models = BasedModel()
```

In [25]:
```python
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
```

In [ ]:
```python
#result
result = BasedLine(df = data, method = weight_mean, models = models, n_splits=10)
```

In [27]:
```python
result.head()
```

Out[27]:

	Model	F1 Score	F1 Score Weighted
0	LR	0.029858	0.936446
1	RF	0.024909	0.937275
2	GBM	0.015238	0.938145
3	ET	0.024117	0.936538
4	XG	0.033978	0.935154

In [31]:
```python
result
```

Out[31]:

	Model	F1 Score	F1 Score Weighted
0	LR	0.029858	0.936446
1	RF	0.024909	0.937275
2	GBM	0.015238	0.938145
3	ET	0.024117	0.936538
4	XG	0.033978	0.935154
5	LG	0.014912	0.938301
6	CAT	0.029119	0.936302

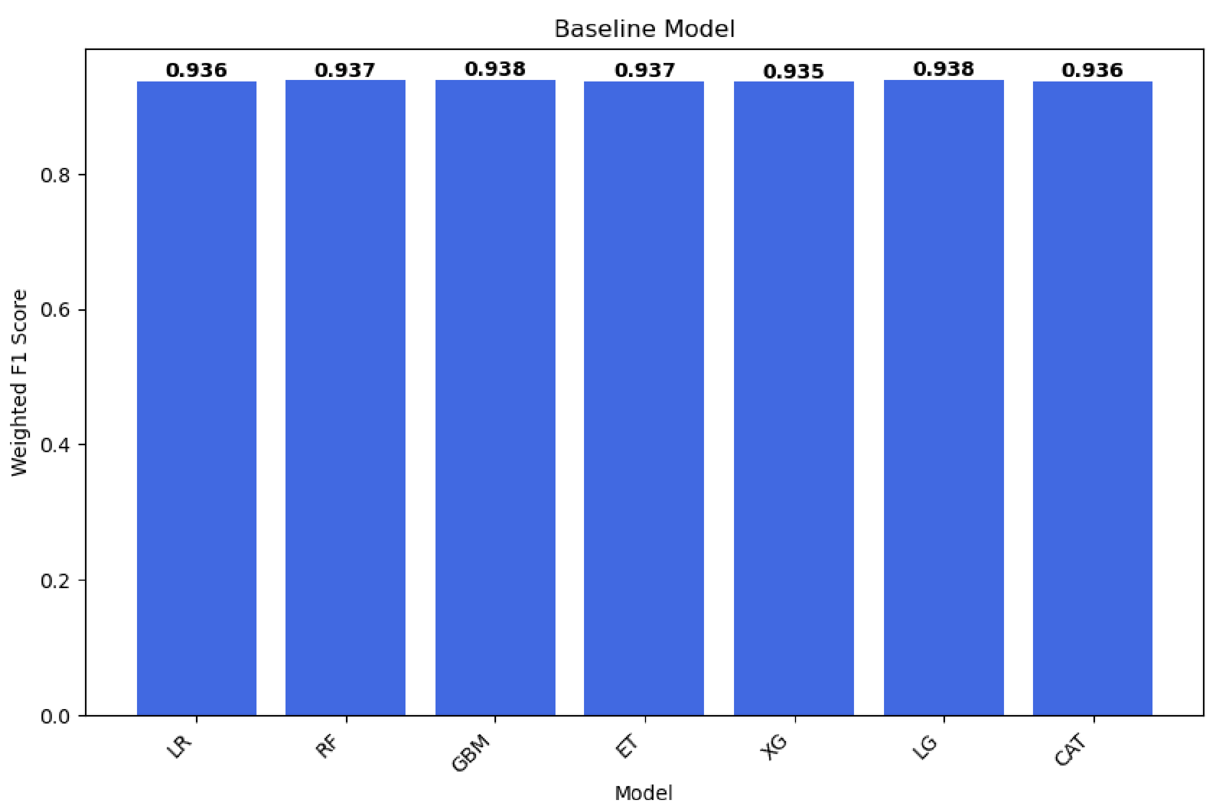
In [112…

```
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 6))
plt.bar(result.Model, result["F1 Score Weighted"], color='royalblue')
plt.xlabel('Model')
plt.ylabel('Weighted F1 Score')
plt.title('Baseline Model')
plt.xticks(rotation=45, ha="right")

# Display the values on top of the bars
for i, v in enumerate(result["F1 Score Weighted"]):
    plt.text(i, v, f"{v:.3f}", ha='center', va='bottom', fontsize=10, fontweight='b

plt.savefig('baselinemodel.png')
```



In [26]:
```
import optuna
```

In [27]:
```
def rm(df):
    start_mem = df.memory_usage().sum() / 1024**2
    print('Memory usage of dataframe is {:.2f} MB'.format(start_mem))
    for col in df.columns:
        col_type = df[col].dtype
        if col_type != object:
            c_min = df[col].min()
            c_max = df[col].max()
            if str(col_type)[:3] == 'int':
                if c_min > np.iinfo(np.int8).min and c_max < np.iinfo(np.int8).max:
                    df[col] = df[col].astype(np.int8)
                elif c_min > np.iinfo(np.int16).min and c_max < np.iinfo(np.int16).
                    df[col] = df[col].astype(np.int16)
                elif c_min > np.iinfo(np.int32).min and c_max < np.iinfo(np.int32).
                    df[col] = df[col].astype(np.int32)
                elif c_min > np.iinfo(np.int64).min and c_max < np.iinfo(np.int64).
                    df[col] = df[col].astype(np.int64)
            else:
                if c_min > np.finfo(np.float16).min and c_max < np.finfo(np.float16
                    df[col] = df[col].astype(np.float16)
                elif c_min > np.finfo(np.float32).min and c_max < np.finfo(np.float
                    df[col] = df[col].astype(np.float32)
                else:
                    df[col] = df[col].astype(np.float64)
        else:
            df[col] = df[col].astype('category')

    end_mem = df.memory_usage().sum() / 1024**2
    print('Memory usage after optimization is: {:.2f} MB'.format(end_mem))
    print('Decreased by {:.1f}%'.format(100 * (start_mem - end_mem) / start_mem))

    return df
```

In [28]:
```
data.weight = data.weight.fillna(85.84)
```

In [29]:
```
optimized_data = rm(df = data)
```

```
Memory usage of dataframe is 29.79 MB
Memory usage after optimization is: 5.25 MB
Decreased by 82.4%
```

In [30]:
```
target_data = optimized_data.readmitted
train_data = optimized_data.drop("readmitted", axis = "columns")
```

In [ ]:

In [31]:
```
def objective(trial , X = train_data, y = target_data):
    train_x , test_x , train_y , test_y = train_test_split(X , y , test_size = 0.2
    params = {
        'tol' : trial.suggest_uniform('tol' , 1e-6 , 1e-3),
        'C' : trial.suggest_loguniform("C", 1e-2, 1),
       'fit_intercept' : trial.suggest_categorical('fit_intercept' , [True, False])
```

```python
        'solver' : trial.suggest_categorical('solver' , ['lbfgs','liblinear']),
         "n_jobs" : -1
    }
    model1 = LogisticRegression(**params, random_state = 2020)
    model1.fit(train_x , train_y)
    y_predlr = model1.predict(test_x)
    ll = f1_score(test_y , y_predlr, average="weighted")
    return ll
```

In [32]:
```python
target_data = optimized_data.readmitted
train_data = optimized_data.drop("readmitted", axis = "columns")
```

In [91]:
```python
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study = optuna.create_study(direction = 'minimize' , study_name = 'lr', pruner = op
study.optimize(objective, n_trials = 50)
print('numbers of the finished trials:' , len(study.trials))
print('the best params:' , study.best_trial.params)
print('the best value:' , study.best_value)
```

```
C:\Users\user\miniconda3\Lib\site-packages\sklearn\linear_model\_logistic.py:1211: U
serWarning: 'n_jobs' > 1 does not have any effect when 'solver' is set to 'liblinea
r'. Got 'n_jobs' = 4.
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r'. Got 'n_jobs' = 4.
  warnings.warn(
numbers of the finished trials: 50
the best params: {'tol': 0.0005960775312811008, 'C': 0.1435333247663179, 'fit_interc
ept': True, 'solver': 'liblinear'}
the best value: 0.8352285603235171
```

- Logistic Regression Result

numbers of the finished trials: 50

the best params: {'tol': 1.080820167727918e-05, 'C': 0.041231805507969725, 'fit_intercept': False, 'solver': 'liblinear'} the best value: 0.8352285603235171

In [81]:
```
data.weight.min()
```

Out[81]:
```
12.0
```

In [92]:
```
def objective_rfc(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'max_depth': trial.suggest_int('max_depth', 5, 30),
        'min_samples_split': trial.suggest_float('min_samples_split', 0.01, 0.5),
        'min_samples_leaf': trial.suggest_float('min_samples_leaf', 0.01, 0.5),
        'max_features': trial.suggest_categorical('max_features', ['sqrt', 'log2'])
        'n_jobs': -1,
        'random_state': 2020
    }

    model = RandomForestClassifier(**params, n_estimators = 1500)
    model.fit(train_x, train_y)
    y_pred_rf = model.predict(test_x)
    f1_weighted = f1_score(test_y, y_pred_rf, average='weighted')
    return f1_weighted
```

In [93]:
```
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study_rfc = optuna.create_study(direction = 'minimize' , study_name = 'rfc', pruner
study_rfc.optimize(objective_rfc, n_trials = 50)
print('numbers of the finished trials:' , len(study_rfc.trials))
print('the best params:' , study_rfc.best_trial.params)
print('the best value:' , study_rfc.best_value)
```

```
numbers of the finished trials: 50
the best params: {'max_depth': 11, 'min_samples_split': 0.08061737763501853, 'min_sa
mples_leaf': 0.4317715692288943, 'max_features': 'sqrt'}
the best value: 0.8332799914115974
```

In [95]:
```

def objective_gbt(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.1),
        'max_depth': trial.suggest_int('max_depth', 3, 10),
        'min_samples_split': trial.suggest_float('min_samples_split', 0.01, 0.5),
        'min_samples_leaf': trial.suggest_float('min_samples_leaf', 0.01, 0.5),
        'max_features': trial.suggest_categorical('max_features', ['sqrt', 'log2'])
        'subsample': trial.suggest_float('subsample', 0.6, 1.0),
        'random_state': 2020
    }

    model = GradientBoostingClassifier(**params, n_estimators=1500)
    model.fit(train_x, train_y)
    y_pred_rf = model.predict(test_x)
```

```
    f1_weighted = f1_score(test_y, y_pred_rf, average='weighted')
    return f1_weighted
```

In [96]:
```
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study_gbt = optuna.create_study(direction = 'minimize' , study_name = 'rfc', pruner
study_gbt.optimize(objective_gbt, n_trials = 50)
print('numbers of the finished trials:' , len(study_gbt.trials))
print('the best params:' , study_gbt.best_trial.params)
print('the best value:' , study_gbt.best_value)
```

```
numbers of the finished trials: 50
the best params: {'learning_rate': 0.03382028862677756, 'max_depth': 6, 'min_samples
_split': 0.22647895404937093, 'min_samples_leaf': 0.02614225027460998, 'max_feature
s': 'sqrt', 'subsample': 0.7900090154646487}
the best value: 0.8332053423959036
```

In [97]:
```
def objective_gb(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.1),
        'max_depth': trial.suggest_int('max_depth', 3, 10),
        'min_child_weight': trial.suggest_float('min_child_weight', 1, 10),
    'gamma': trial.suggest_float('gamma', 0.0, 1.0),
        'objective': 'binary:logistic',
        'eval_metric': 'logloss',
        'n_jobs': -1,
        'random_state': 2020
    }

    model = XGBClassifier(**params)
    model.fit(train_x, train_y)
    y_pred_xgb = model.predict(test_x)
    f1_weighted = f1_score(test_y, y_pred_xgb, average='weighted')
    return f1_weighted
```

In [98]:
```
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study_gb = optuna.create_study(direction = 'minimize' , study_name = 'rfc', pruner
study_gb.optimize(objective_gb, n_trials = 50)
print('numbers of the finished trials:' , len(study_gbt.trials))
print('the best params:' , study_gb.best_trial.params)
print('the best value:' , study_gb.best_value)
```

```
numbers of the finished trials: 50
the best params: {'learning_rate': 0.05485777506438099, 'max_depth': 3, 'min_child_w
eight': 9.99024896255534, 'gamma': 0.012971846771630838}
the best value: 0.8335453728091722
```

In [99]:
```
def objective_lgb(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.1),
        'max_depth': trial.suggest_int('max_depth', 3, 10),
        'num_leaves': trial.suggest_int('num_leaves', 31, 1023),
        'min_child_samples': trial.suggest_int('min_child_samples', 1, 20),
```

```python
        'subsample': trial.suggest_float('subsample', 0.6, 1.0),
        'colsample_bytree': trial.suggest_float('colsample_bytree', 0.6, 1.0),
        'subsample_freq': trial.suggest_int('subsample_freq', 1, 5),
        'reg_alpha': trial.suggest_loguniform('reg_alpha', 1e-9, 10.0),
        'reg_lambda': trial.suggest_loguniform('reg_lambda', 1e-9, 10.0),
        'n_jobs': -1,
        'random_state': 2020
    }

    model = LGBMClassifier(**params, n_estimators=1500)
    model.fit(train_x, train_y)
    y_pred_lgbm = model.predict(test_x)
    f1_weighted = f1_score(test_y, y_pred_lgbm, average='weighted')
    return f1_weighted
```

In [100…

```python
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study_lgb = optuna.create_study(direction = 'minimize' , study_name = 'lgb', pruner
study_lgb.optimize(objective_lgb, n_trials = 50)
print('numbers of the finished trials:' , len(study_lgb.trials))
print('the best params:' , study_lgb.best_trial.params)
print('the best value:' , study_lgb.best_value)
```

```
numbers of the finished trials: 50
the best params: {'learning_rate': 0.010086960882768474, 'max_depth': 3, 'num_leave
s': 451, 'min_child_samples': 19, 'subsample': 0.9050537971807502, 'colsample_bytre
e': 0.9832730500853207, 'subsample_freq': 2, 'reg_alpha': 2.114000183874016e-06, 're
g_lambda': 0.019156374967296726}
the best value: 0.8343813620618454
```

In [33]:

```python
def objective_cat(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'max_depth': trial.suggest_int('max_depth', 3, 10),
        'min_child_samples': trial.suggest_int('min_child_samples', 1, 20),
        'colsample_bylevel': trial.suggest_float('colsample_bylevel', 0.6, 1.0),
        'subsample': trial.suggest_float('subsample', 0.6, 1.0),
        'l2_leaf_reg': trial.suggest_loguniform('l2_leaf_reg', 1e-9, 10.0),
        'random_state': 2020,
        'silent': True
    }

    model = CatBoostClassifier(**params, n_estimators = 1500)
    model.fit(train_x, train_y)
    y_pred_catboost = model.predict(test_x)
    f1_weighted = f1_score(test_y, y_pred_catboost, average='weighted')
    return f1_weighted
```

In [34]:

```python
def print_trials(study, trial):
    print(f"Trial {trial.number} - Value: {trial.value:.6f}")
    if trial.state == optuna.trial.TrialState.FAIL:
        print(f"Trial {trial.number} failed.")
```

In [35]:

```python
optuna.logging.set_verbosity(optuna.logging.WARNING)  # Set the verbosity to a mini
study_cat = optuna.create_study(direction='minimize',study_name='cat',pruner=optuna
study_cat.optimize(objective_cat, n_trials=50, callbacks=[print_trials])
```

```python
print('Numbers of the finished trials:', len(study_cat.trials))
print('The best params:', study_cat.best_trial.params)
print('The best value:', study_cat.best_value)
```

```
Trial 0 - Value: 0.836469
Trial 1 - Value: 0.835875
Trial 2 - Value: 0.836796
Trial 3 - Value: 0.836009
Trial 4 - Value: 0.835864
Trial 5 - Value: 0.834931
Trial 6 - Value: 0.835757
Trial 7 - Value: 0.836637
Trial 8 - Value: 0.835705
Trial 9 - Value: 0.836928
Trial 10 - Value: 0.835435
Trial 11 - Value: 0.834973
Trial 12 - Value: 0.835435
Trial 13 - Value: 0.836087
Trial 14 - Value: 0.835016
Trial 15 - Value: 0.836284
Trial 16 - Value: 0.836298
Trial 17 - Value: 0.835544
Trial 18 - Value: 0.835958
Trial 19 - Value: 0.835229
Trial 20 - Value: 0.835812
Trial 21 - Value: 0.835674
Trial 22 - Value: 0.835648
Trial 23 - Value: 0.836495
Trial 25 - Value: 0.836020
Trial 26 - Value: 0.835358
Trial 27 - Value: 0.836298
Trial 28 - Value: 0.835760
Training has stopped (degenerate solution on iteration 1136, probably too small l2-r
egularization, try to increase it)
Trial 30 - Value: 0.836088
Trial 31 - Value: 0.835617
Trial 32 - Value: 0.835787
Trial 33 - Value: 0.835879
Trial 34 - Value: 0.835918
Trial 35 - Value: 0.835849
Trial 36 - Value: 0.836560
Trial 37 - Value: 0.835849
Training has stopped (degenerate solution on iteration 678, probably too small l2-re
gularization, try to increase it)
```

```
Trial 38 - Value: 0.836600
Trial 39 - Value: 0.835864
Trial 40 - Value: 0.834777
Trial 41 - Value: 0.835409
Trial 42 - Value: 0.834760
Trial 43 - Value: 0.835093
Trial 44 - Value: 0.835994
Trial 45 - Value: 0.836298
Trial 46 - Value: 0.835212
Trial 47 - Value: 0.837228
Trial 48 - Value: 0.836046
Trial 49 - Value: 0.835076
Numbers of the finished trials: 50
The best params: {'max_depth': 10, 'min_child_samples': 9, 'colsample_bylevel': 0.64
27255573185624, 'subsample': 0.7813719342485228, 'l2_leaf_reg': 7.2621009570354215e-
06}
The best value: 0.8342902290969217
```

In [ ]:

In [29]:
```python
def objective_EXT(trial, X=train_data, y=target_data):
    train_x, test_x, train_y, test_y = train_test_split(X, y, test_size=0.2, random

    params = {
        'max_depth': trial.suggest_int('max_depth', 5, 30),
        'min_samples_split': trial.suggest_float('min_samples_split', 0.01, 0.5),
        'min_samples_leaf': trial.suggest_float('min_samples_leaf', 0.01, 0.5),
        'max_features': trial.suggest_categorical('max_features', ['sqrt', 'log2'])
        'n_jobs': -1,
        'random_state': 2020
    }

    model = ExtraTreesClassifier(**params, n_estimators = 1500)
    model.fit(train_x, train_y)
    y_pred_et = model.predict(test_x)
    f1_weighted = f1_score(test_y, y_pred_et, average='weighted')
    return f1_weighted
```

In [32]:
```python
optuna.logging.set_verbosity(optuna.logging.WARNING) # i do not want to see trail i
study_ext = optuna.create_study(direction = 'minimize' , study_name = 'ext', pruner
study_ext.optimize(objective_EXT, n_trials = 50)
print('numbers of the finished trials:' , len(study_ext.trials))
print('the best params:' , study_ext.best_trial.params)
print('the best value:' , study_ext.best_value)
```

```
numbers of the finished trials: 50
the best params: {'max_depth': 26, 'min_samples_split': 0.021711052309274226, 'min_s
amples_leaf': 0.472092158052296, 'max_features': 'sqrt'}
the best value: 0.8332799914115974
```

OPTIMISED RESULT

In [45]:
```python
log_param = {'tol': 0.0005960775312811008, 'C': 0.1435333247663179, 'fit_intercept'
rfc_param = {'max_depth': 11, 'min_samples_split': 0.08061737763501853,'min_samples
```

```python
gbt_param = {'learning_rate': 0.03382028862677756, 'max_depth': 6, 'min_samples_spl
ext_param = {'max_depth': 26, 'min_samples_split': 0.021711052309274226, 'min_sampl
xg_param = {'learning_rate': 0.05485777506438099, 'max_depth': 3, 'min_child_weight
lg_param = {'learning_rate': 0.010086960882768474, 'max_depth': 3, 'num_leave': 451
cat_param = {'max_depth': 10, 'min_child_samples': 9, 'colsample_bylevel': 0.642725
```

In [46]:

```python
def OptimizedModel():
    optimizedModels = []
    optimizedModels.append(('LR'   , LogisticRegression(**log_param)))
    optimizedModels.append(('RF'   , RandomForestClassifier(**rfc_param, n_estimato
    optimizedModels.append(('GBM'  , GradientBoostingClassifier(**gbt_param, n_esti
    optimizedModels.append(('ET'   , ExtraTreesClassifier(**ext_param, n_estimators
    optimizedModels.append(('XG'   , XGBClassifier(**xg_param, n_estimators = 1500)
    optimizedModels.append(('LG'   , LGBMClassifier(**lg_param, n_estimators = 1500
    optimizedModels.append(('CAT'   , CatBoostClassifier(**cat_param, n_estimators
    return optimizedModels
```

In [47]:

```python
optimized_model = OptimizedModel()
```

In [48]:

```python
#result
optimized_result = BasedLine(df = data, method = weight_mean, models = optimized_mo
```

```
Running LR: 100%|████████████████████████████████████████████████████████████████████
███| 10/10 [01:23<00:00,  8.33s/it]
Running RF: 100%|████████████████████████████████████████████████████████████████████
███| 10/10 [08:39<00:00, 51.90s/it]
Running GBM: 100%|███████████████████████████████████████████████████████████████████
██| 10/10 [50:55<00:00, 305.59s/it]
Running ET: 100%|████████████████████████████████████████████████████████████████████
███| 10/10 [06:35<00:00, 39.52s/it]
Running XG: 100%|████████████████████████████████████████████████████████████████████
███| 10/10 [14:28<00:00, 86.88s/it]
Running LG:   0%|
| 0/10 [00:00<?, ?it/s]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  10%|███████
| 1/10 [00:14<02:09, 14.39s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  20%|██████████████▏
| 2/10 [00:28<01:54, 14.36s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  30%|█████████████████████▍
| 3/10 [00:43<01:42, 14.71s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  40%|████████████████████████████▌
| 4/10 [01:05<01:43, 17.27s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  50%|████████████████████████████████████
| 5/10 [01:18<01:18, 15.80s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  60%|███████████████████████████████████████████
| 6/10 [01:33<01:01, 15.46s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
```

```
Running LG:  70%|███████████████████████████▍
| 7/10 [01:46<00:44, 14.75s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  80%|███████████████████████████████▏
| 8/10 [01:58<00:28, 14.04s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG:  90%|██████████████████████████████████▉
| 9/10 [02:23<00:17, 17.35s/it]
[LightGBM] [Warning] Unknown parameter: num_leave
Running LG: 100%|██████████████████████████████████
██| 10/10 [02:36<00:00, 15.67s/it]
Running CAT: 100%|█████████████████████████████████
█| 10/10 [39:22<00:00, 236.21s/it]
| Model    |     F1 Score |    F1 Score Weighted |
|---------+-------------+---------------------|
| LR       | 0.0220447   |             0.93759  |
| RF       | 0           |             0.939869 |
| GBM      | 0.000879353 |             0.939712 |
| ET       | 0           |             0.939869 |
| XG       | 0.0214954   |             0.937261 |
| LG       | 0.0150896   |             0.938431 |
| CAT      | 0.0195913   |             0.937081 |
Execution time: 7441.22 seconds
```

In [49]:

```python
optimized_result
```

Out[49]:

	Model	F1 Score	F1 Score Weighted
0	LR	0.022045	0.937590
1	RF	0.000000	0.939869
2	GBM	0.000879	0.939712
3	ET	0.000000	0.939869
4	XG	0.021495	0.937261
5	LG	0.015090	0.938431
6	CAT	0.019591	0.937081

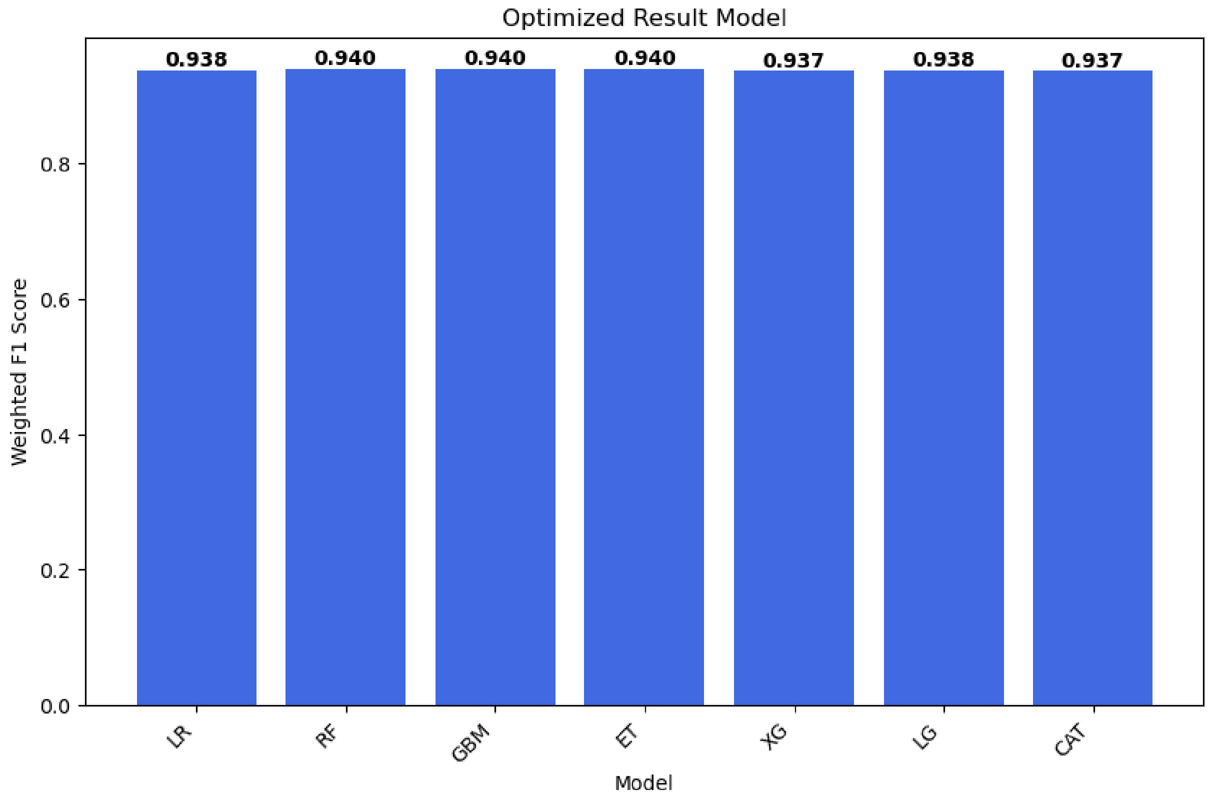
In [53]:

```python
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 6))
plt.bar(optimized_result.Model, optimized_result["F1 Score Weighted"], color='royal
plt.xlabel('Model')
plt.ylabel('Weighted F1 Score')
plt.title('Optimized Result Model')
plt.xticks(rotation=45, ha="right")

# Display the values on top of the bars
for i, v in enumerate(optimized_result["F1 Score Weighted"]):
    plt.text(i, v, f"{v:.3f}", ha='center', va='bottom', fontsize=10, fontweight='b
```

```
plt.savefig('optimized_result_bar.png')
```



SHAP ANALYSIS

In [56]:
```
train_x, test_x, train_y, test_y = train_test_split(train_data, target_data, test_s
```

In [94]:
```
# Prepares a default instance of the random forest regressor
#model = RandomForestClassifier(**rfc_param, n_estimators=1500)
model = LGBMClassifier(**lg_param, n_estimators=1500)
model2 = LogisticRegression(**log_param)
model3 = XGBClassifier(**xg_param, n_estimator=1500)


# Fits the model on the data
model.fit(train_x, train_y)
```

```
[LightGBM] [Warning] Unknown parameter: num_leave
```

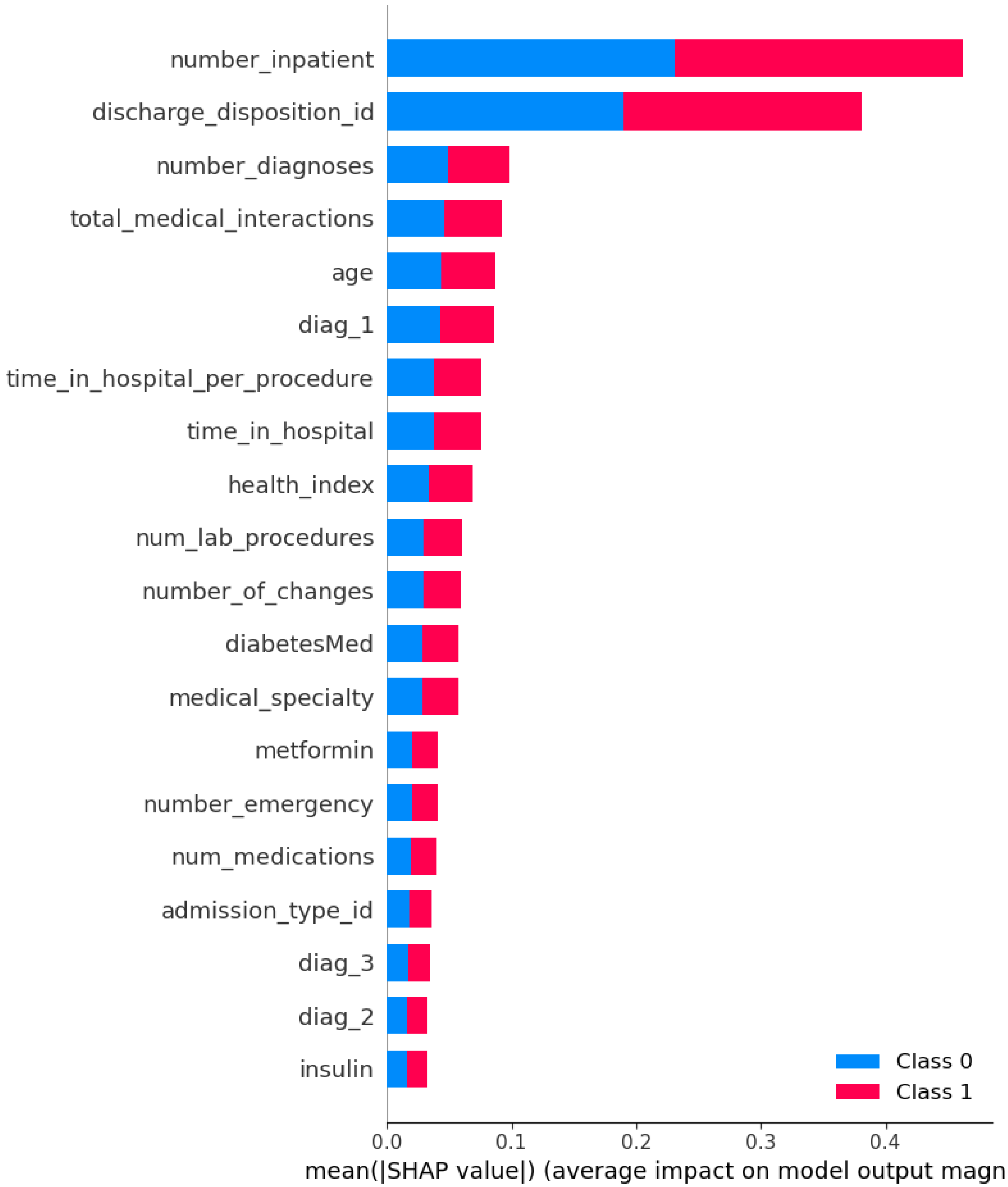
Out[94]:
```
▾                          LGBMClassifier
LGBMClassifier(colsample_bytree=0.9832730500853207,
               learning_rate=0.010086960882768474, max_depth=3,
               min_child_samples=19, n_estimators=1500, num_leave=451,
               reg_alpha=2.114e-06, reg_lambda=0.019156374967296726,
               subsample=0.9050537971807502, subsample_freq=2)
```

In [59]:
```
import shap
```

In [80]:
```
explainer = shap.TreeExplainer(model)
shap_values = explainer.shap_values(test_x)
```

```
LightGBM binary classifier with TreeExplainer shap values output has changed to a li
st of ndarray
```

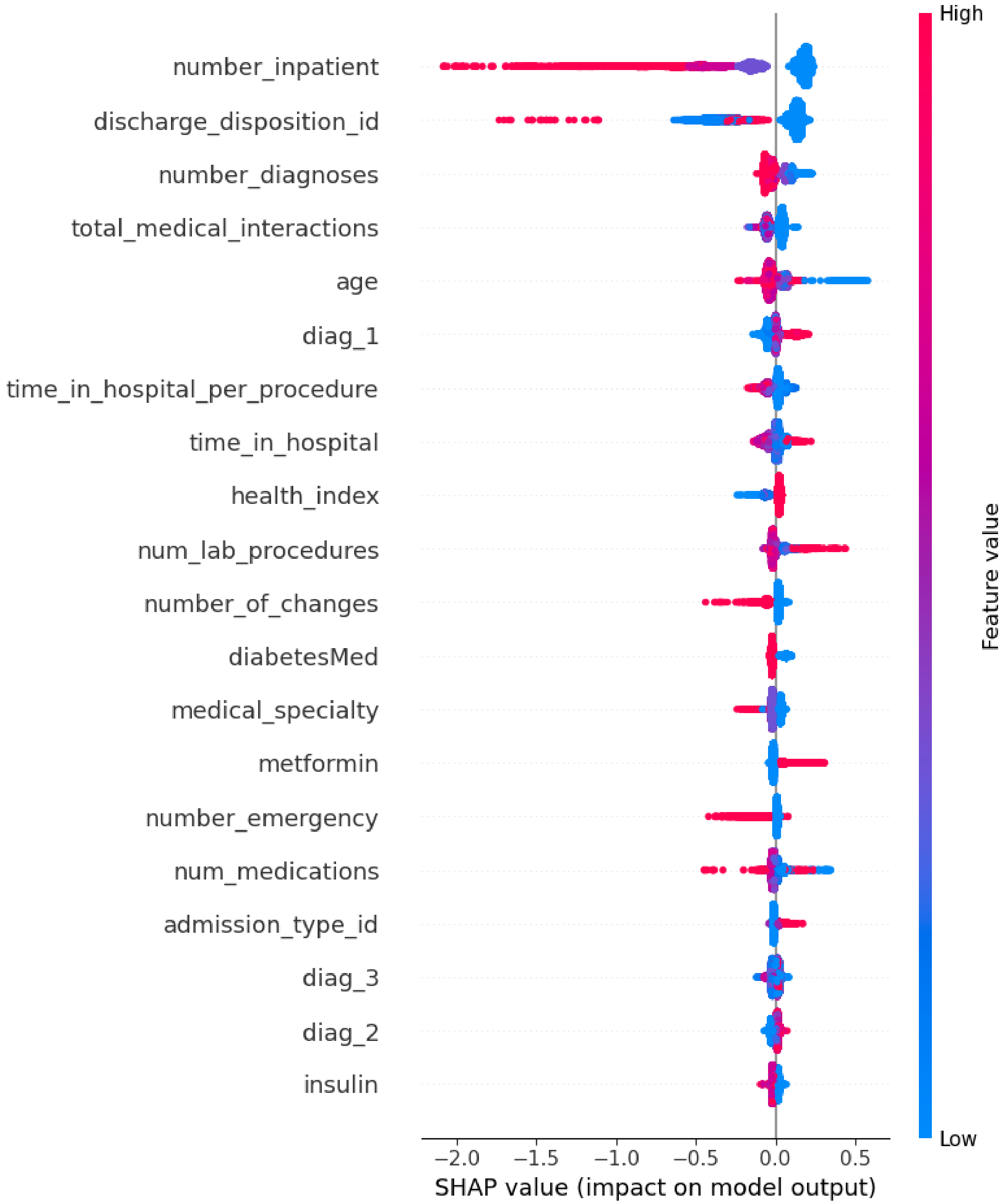
In [69]:
```
shap.summary_plot(shap_values, test_x)
```




```
<Figure size 640x480 with 0 Axes>
```

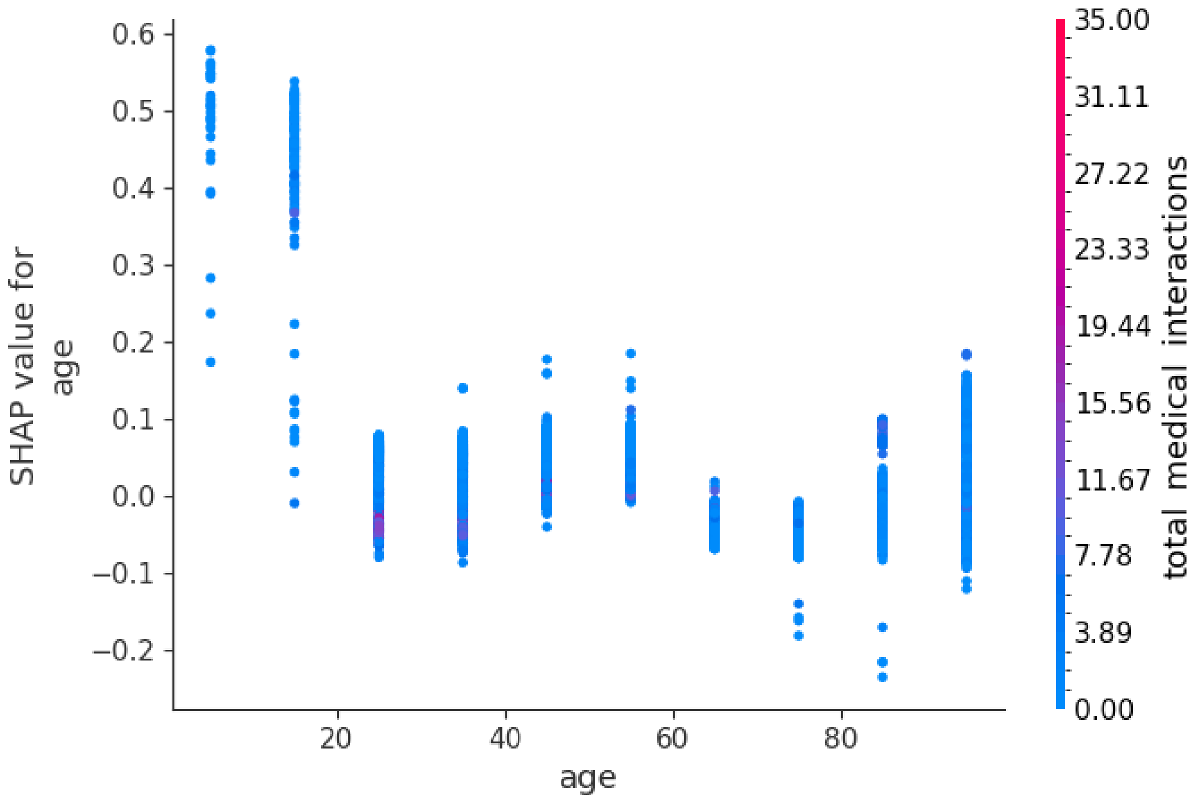
In [90]:
```
shap.summary_plot(shap_values[0], test_x)
```

```
No data for colormapping provided via 'c'. Parameters 'vmin', 'vmax' will be ignored
```



In [93]:

```
shap.dependence_plot("age", shap_values[0], test_x,interaction_index="total_medical
```

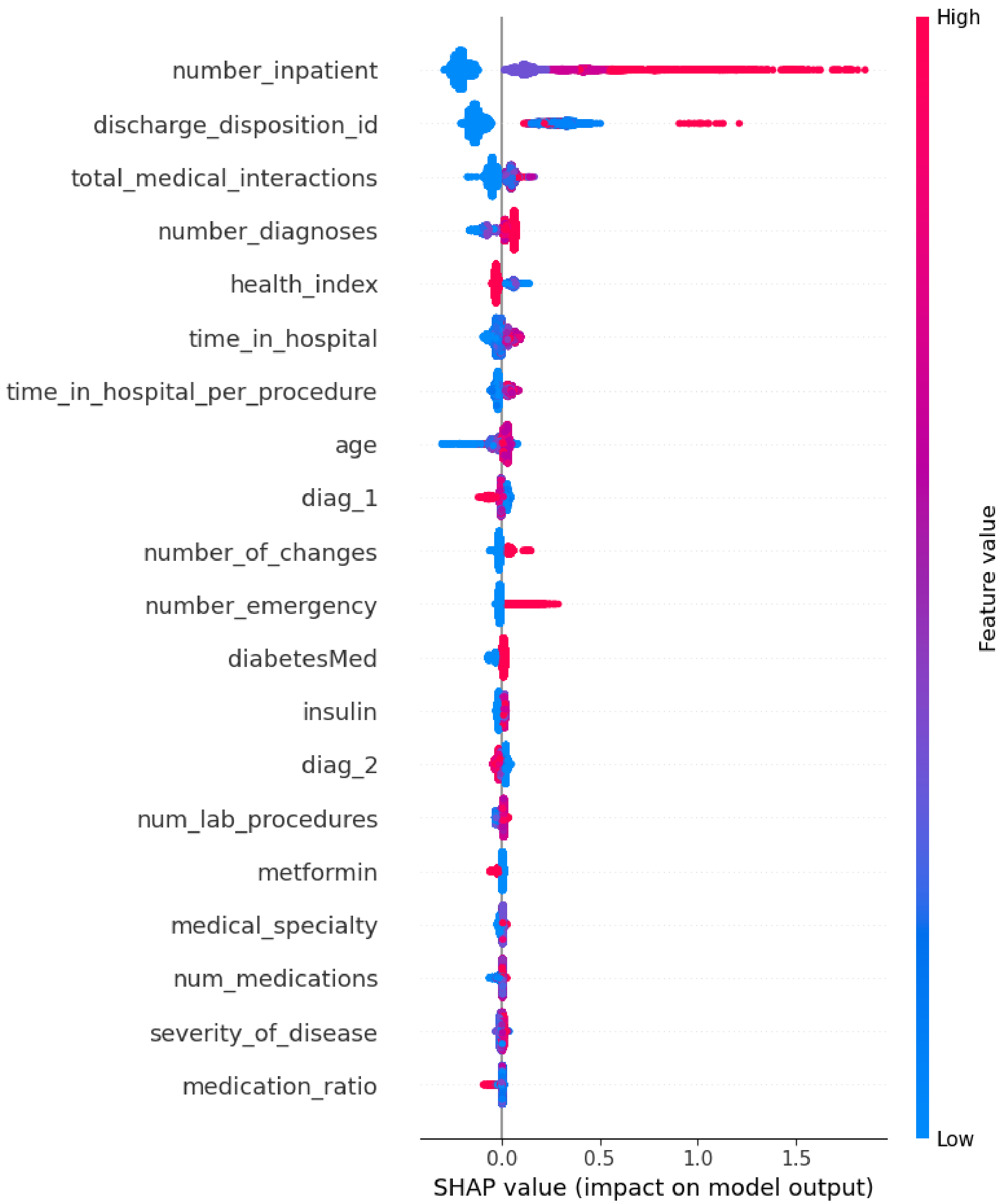


In [95]:
```
model3.fit(train_x, train_y)
explainer = shap.TreeExplainer(model3)
shap_values = explainer.shap_values(test_x)
```

```
[03:58:31] WARNING: C:\Users\dev-admin\croot2\xgboost-split_1675461376218\work\src\learner.cc:767:
Parameters: { "n_estimator" } are not used.
```

In [96]:
```
shap.summary_plot(shap_values, test_x)
```

```
No data for colormapping provided via 'c'. Parameters 'vmin', 'vmax' will be ignored
```



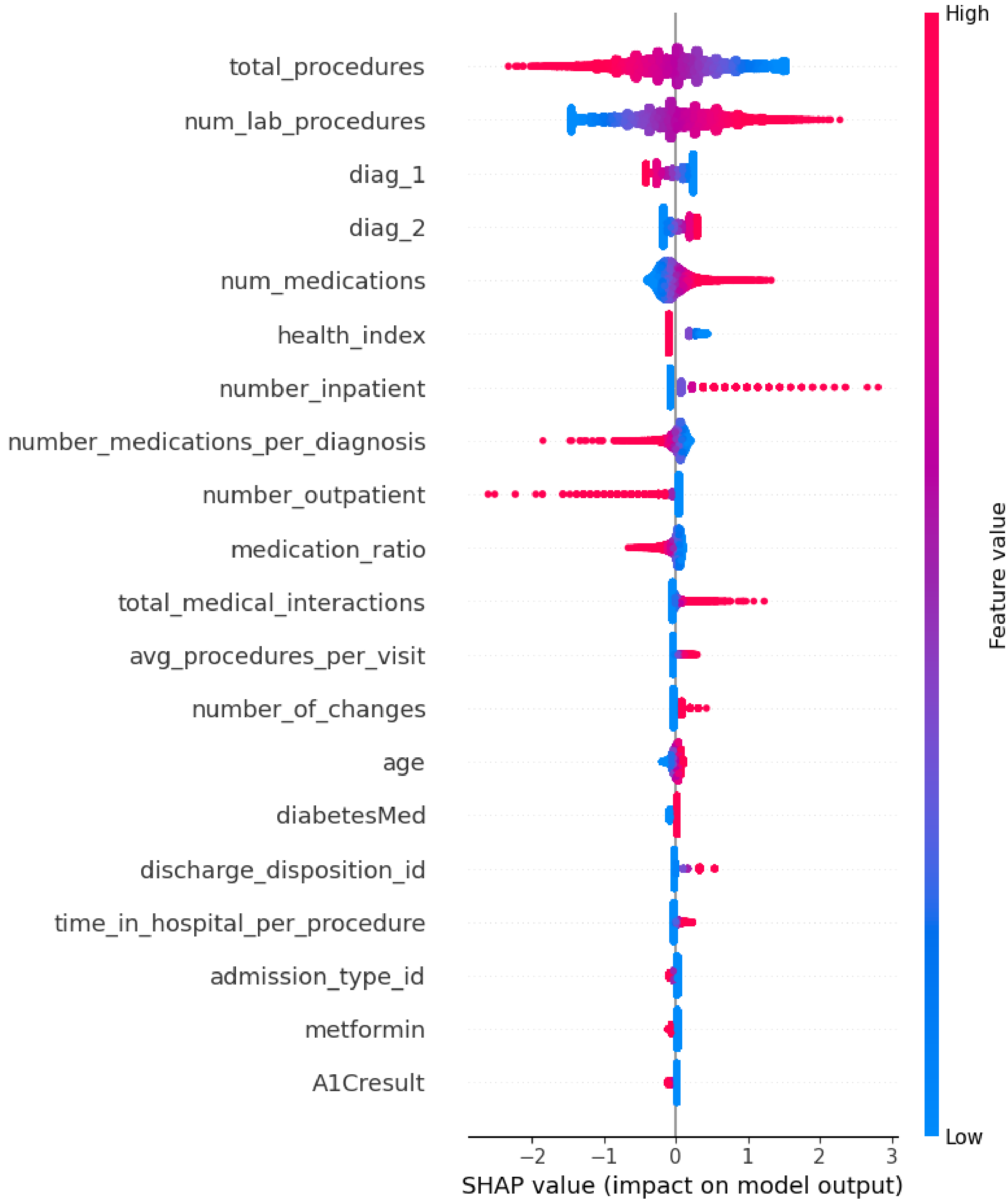
In [100…

```
model2.fit(train_x, train_y)
explainer = shap.Explainer(model2, test_x)
shap_values = explainer.shap_values(test_x)
```

In [103…

```
shap.summary_plot(shap_values, test_x)
```

```
No data for colormapping provided via 'c'. Parameters 'vmin', 'vmax' will be ignored
```


total_procedures
num_lab_procedures
diag_1
diag_2
num_medications
health_index
number_inpatient
number_medications_per_diagnosis
number_outpatient
medication_ratio
total_medical_interactions
avg_procedures_per_visit
number_of_changes
age
diabetesMed
discharge_disposition_id
time_in_hospital_per_procedure
admission_type_id
metformin
A1Cresult
−2
−1
0
1
2
3
SHAP value (impact on model output)
High
Low
Feature value

```
In [ ]:
```