RESEARCH LETTER

Home Dialysis Prediction Using Artificial Intelligence

To the Editor:

Home dialysis, in the form of peritoneal dialysis (PD) or home hemodialysis (HHD), provides patients receiving kidney replacement therapy (KRT) an alternative to in-center hemodialysis (ICHD). A strong evidence base suggests that home dialysis results in higher quality of life and lower costs than ICHD and is associated with equivalent, if not improved, survival.[1-4] Despite such advantages, and high rates of medical eligibility, home dialysis accounts for only 14.5% of KRT in the United States.[3,5,6]

In a large dialysis organization (Fresenius Kidney Care [FKC]), utilization of home dialysis across hospital referral regions (HRRs)[7] with more than one center ranges from 2.2%-47.9%. We aimed to characterize the predictors of home dialysis utilization and estimate rates potentially achievable if practice patterns employed in areas with high utilization were applied nationwide.

Deidentified data from FKC were extracted as of December 31, 2019 (N = 198,684). A machine learning model was built to predict patient dialysis modality for patients living outside of an institution (eg, nursing homes) (N = 183,097). The machine learning model was trained using data from the 20% of HRRs with the highest home dialysis rates. A total of 768 predictors were evaluated in the present model (Table S1). The complete methodology is provided in Item S1.

Of the 306 HRRs in the United States, FKC operates in 265, with an average home dialysis rate of 17.3% in 2019 (Fig S1). Among all patients, the rate of home dialysis was 15.2% at the end of 2019. Across the top quintile of HRRs (Fig S2), the mean rate of home dialysis was 29.1%.

Evaluation of model performance on test data demonstrated an area under the receiver operating characteristic curve (AUROC) of 0.80, 0.75, and 0.79 for ICHD, HHD, and PD, respectively (Fig S3A), and 0.80 when binarized to ICHD vs home dialysis (HHD + PD). As expected, the AUROC was slightly worse when applied to the bottom markets (Fig S3B), whereas precision was notably worse as the model identified home dialysis candidates in these

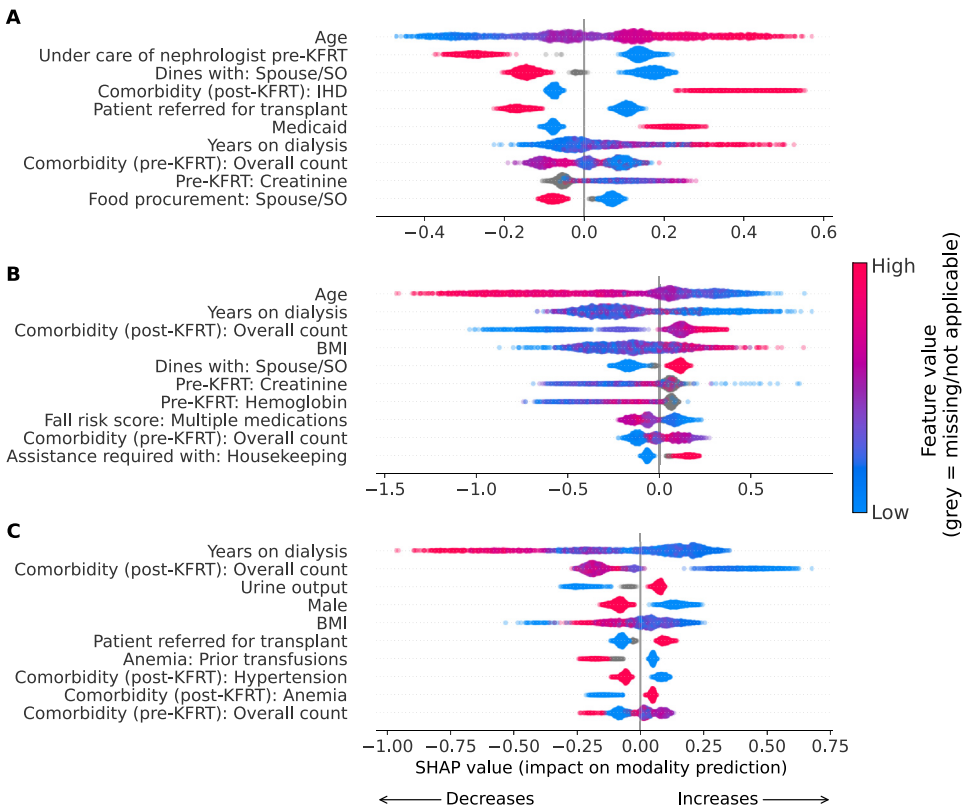

Figure 1. Top 10 important predictors for (A) ICHD, (B) HHD, and (C) PD in the machine learning model ranked in descending order by mean absolute Shapley values. Each dot represents an individual observation (patient) and how their value for a given feature influenced the model's prediction that they were or were not on that modality. Dots farther to the right indicate values that increase the prediction score of being on that modality, and dots farther to the left indicate values that decrease the predicted score. For continuous predictors, red indicates higher values, and blue indicates lower values. For categorical predictors, red indicates yes, and blue indicates no. Gray indicates not applicable or missing data. Abbreviations: BMI, body mass index; HHD, home hemodialysis; ICHD, in-center hemodialysis; IHD, ischemic heart disease; KFRT, kidney failure replacement therapy; PD, peritoneal dialysis; SHAP, Shapley additive explanations; SO, significant other.

bottom markets who were receiving dialysis in-center (Table S2).

Across the model, the top predictors of dialysis modality included age, pre- and post-KRT comorbid conditions, dialysis vintage, body mass index, spouse/significant other interactions, pre-dialysis care by a nephrologist, pre-KRT creatinine and hemoglobin levels, and referral for a transplant (Fig 1). Age was the top predictor for ICHD and HHD; older age predicted ICHD and younger age predicted HHD. The top predictor of PD was shorter dialysis vintages.

Implementing current practices from the HRRs with the highest home penetration rates is predicted to increase home dialysis rates across HRRs by over 60% (from 17.3%-27.8%; Fig S1). Such rates may be achieved without implementation of proposed changes and incentives across the health care system. Conversely, systemic changes would likely need to be adopted to further increase rates of home dialysis beyond 30%.

As evidenced by the variation in the modeled home penetration rates (Fig S2), patient characteristics greatly influence home dialysis rates. Although patients on home therapy tend to be younger and have shorter dialysis vintages in top and bottom markets (Table S3), there are also higher acuity patient characteristics that increase the prediction of being on a home modality, such as more comorbid conditions documented pre- and post-KRT initiation and post-KRT documented anemia (Fig 1, B-C). In line with this, very few patients are medically ineligible for home dialysis, and in fact, home dialysis may be associated with benefits for patients with some comorbid conditions (eg, cardiovascular disease and anemia).[5,8,9]

Because the present study used data extracted before the coronavirus disease 2019 pandemic, we are unable to characterize whether predictors of home dialysis have changed in a postpandemic environment. Similarly, this study does not reflect any systemic changes because of the Advancing American Kidney Health initiative announced in 2019 or impact of changes to payment models implemented thereafter. Despite varying familiarity with home dialysis and variable commitment to shared decision making contributing to low home dialysis utilization,[10] by design, the present study excludes any clinician or facility characteristics that may predict home dialysis to demonstrate the potential impact of removing these barriers. Although there are some differences in patient characteristics between top and remaining markets (Table S3), the predicted increase in home dialysis rates when applying the model to the withheld data suggests this is not a major factor behind higher home penetration rates in the top markets.

Implementing broader patient selection criteria as in top performing markets is integral to expanding home dialysis. Using machine learning, we predict that nationwide home dialysis rates could increase to >27% by applying the practices already in place across the top HRRs. Differences across patient populations will greatly affect the rates achievable with these criteria and should be considered when setting goals for home dialysis utilization.

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SUPPLEMENTARY MATERIALS

Supplementary File (PDF)

Figure S1: HRR home dialysis penetration rates and top versus bottom HRR distribution.

Figure S2: Predicted rates of home dialysis (PD + HHD) use among US patients receiving kidney failure replacement therapy across HRRs.

Figure S3: Area under the receiver operating characteristic curve (AUROC) of **(A)** test data from the quintile of HRRs with the highest home dialysis rates (N = 3,161), and **(B)** remaining (quintiles 2–5) HRRs (N = 162,026).

Table S1: Data Source Categories and Elements of All 768 Variables Used in Training the Model with Missingness.

Table S2: Discrimination and Calibration Metrics for Model Performance on Test Data (Top HRRs Unseen by Model During Training) and Withheld Data (Bottom HRRs).

Table S3: Patient Characteristics by Top Markets (Used to Train and Test Model) and Bottom Markets (Withheld Data Used to Predict National Rates) and by Modality for Each Market.

Item S1: Detailed methods.

ARTICLE INFORMATION

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