

Supplementary Materials

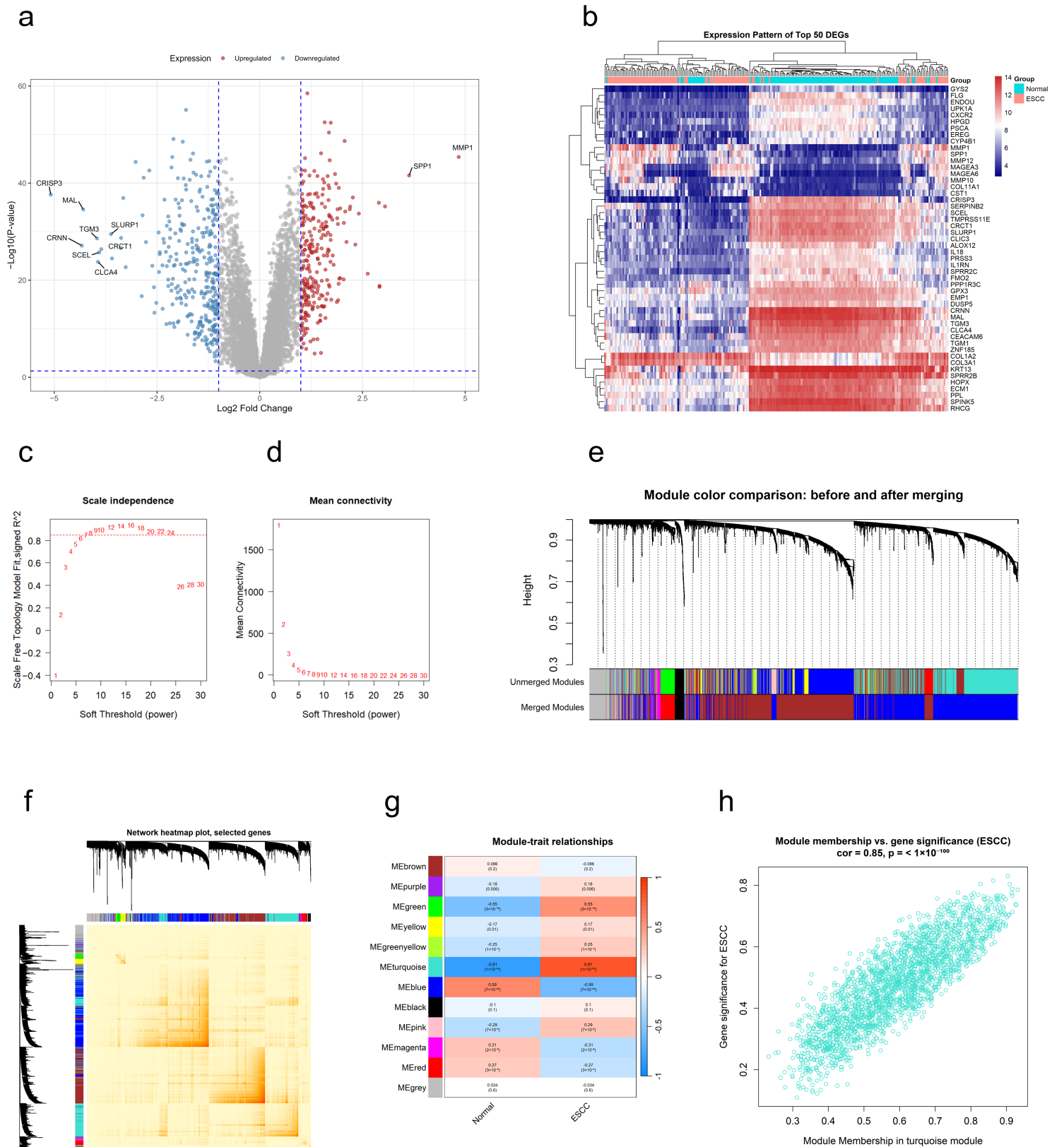


Figure S1. Acquisition of ESCC targets. **(a)** Volcanic map showing DEGs. **(b)** Top 50 DEGs heatmap. **(c,d)** Scale independence and average connectivity analysis in WGCNA. **(e)** WGCNA modules identified by color. **(f)** Gene module correlation network heatmap. **(g)** Module-trait correlations for all 12 modules. **(h)** Scatter plot of GS against MM for the turquoise module.

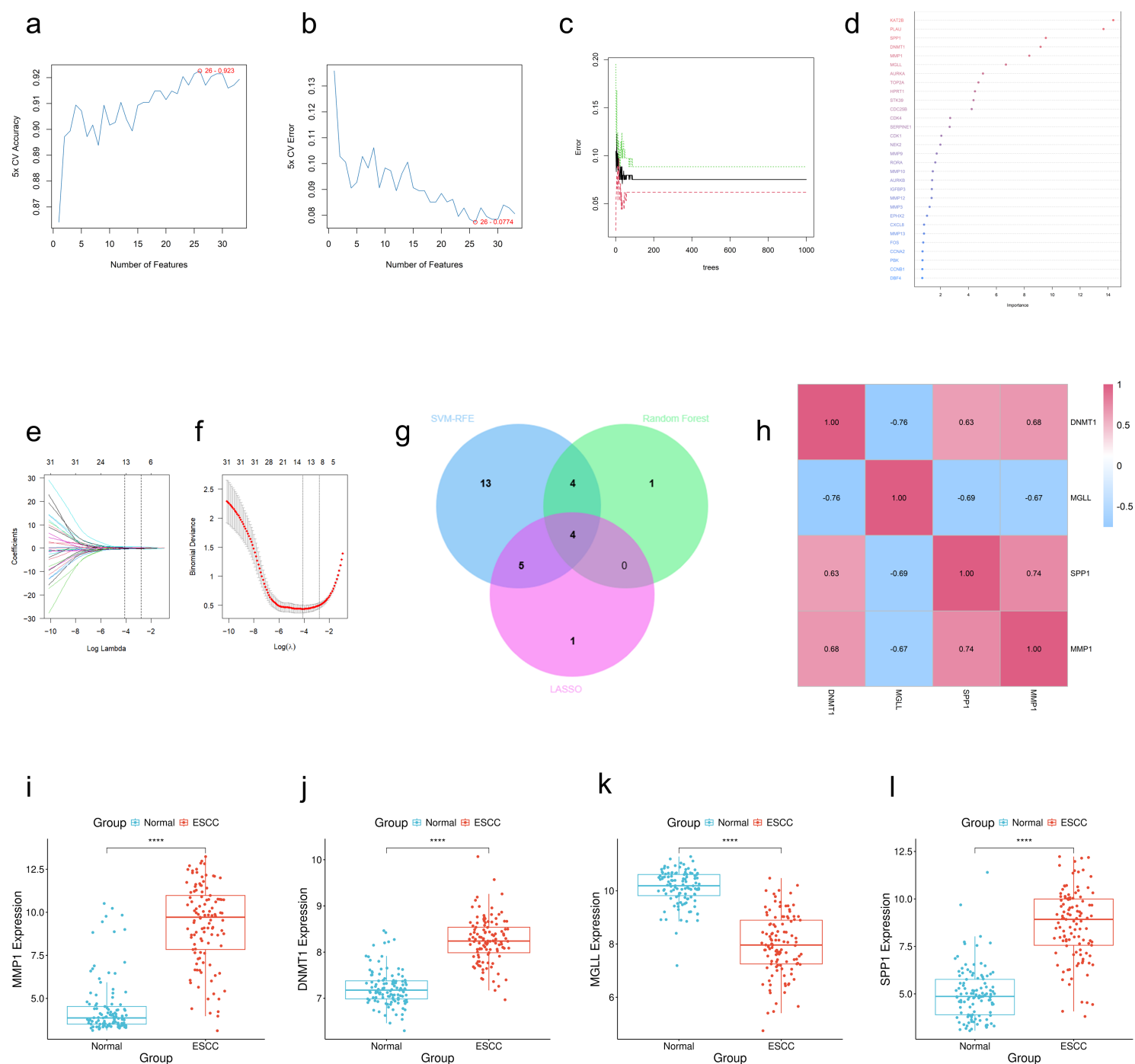


Figure S2. Machine learning-based hub gene screening. **(a, b)** 5-fold cross-validation accuracy vs. error rate curves for the SVM-RFE algorithm. **(c, d)** Error rate curves vs. significance assessment for the Random Forest algorithm. **(e, f)** Coefficients vs. regularized path plots for LASSO regression. **(g)** Venn diagram for key hub gene screening. **(h)** Heatmap analysis of expression correlations among hub genes. **(i-l)** Boxplots of hub gene expression levels based on the GSE44021 dataset (****: $p < 0.0001$).

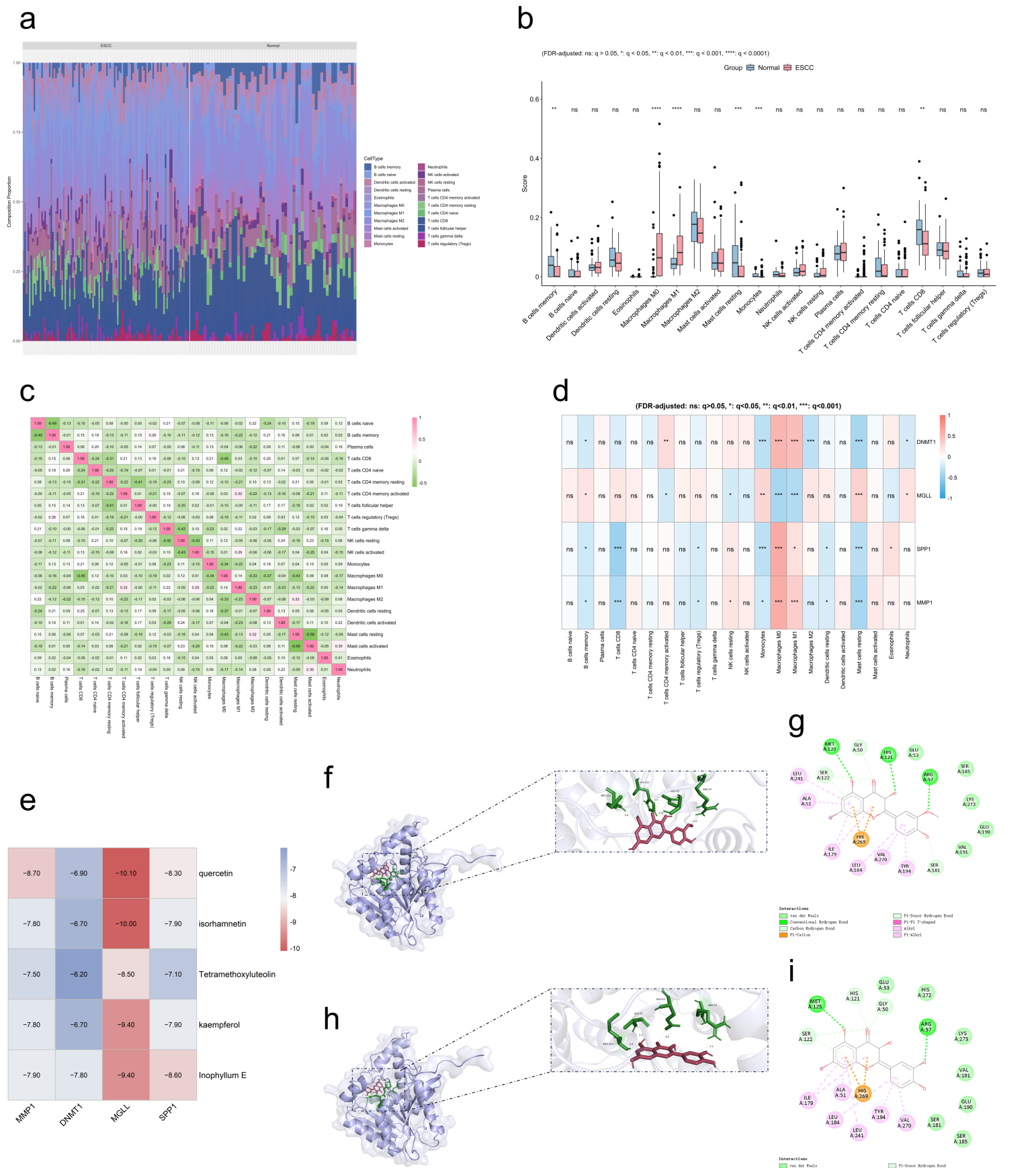


Figure S3. Immune infiltration analysis and molecular docking validation (ESCC). **(a)** Stacked bar graph showing immune cell infiltration in samples (GSE44021 dataset). **(b)** Box plot illustrating differential immune cell infiltration in esophageal squamous carcinoma versus normal samples. **(c)** Heatmap displaying correlations among immune cell types. **(d)** Hub gene-immune cell infiltration correlation (heatmap). **(e)** Binding energy heatmap (kcal/mol). **(f, g)** Docking pose diagrams of isorhamnetin to *MGLL* (-10.00 kcal/mol). **(h, i)** Docking pose diagrams of quercetin to *MGLL* (-10.10 kcal/mol).

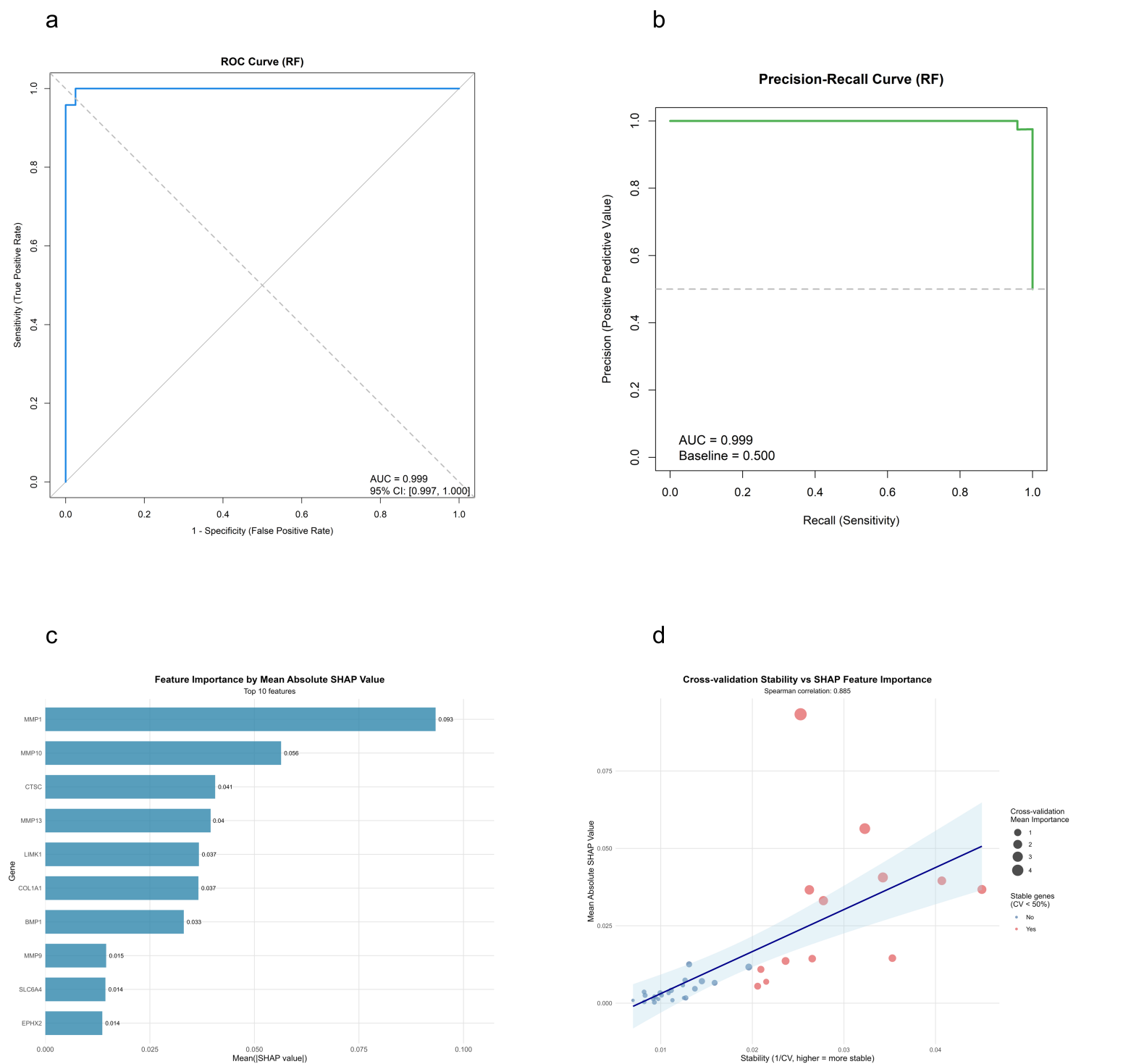


Figure S4. Performance evaluation of the RF model and SHAP-based feature interpretability analysis. **(a)** ROC curve. **(b)** PR curve. **(c)** feature importance bar plot. **(d)** correlation scatter plot of cross-validation stability versus SHAP feature importance for the RF model.

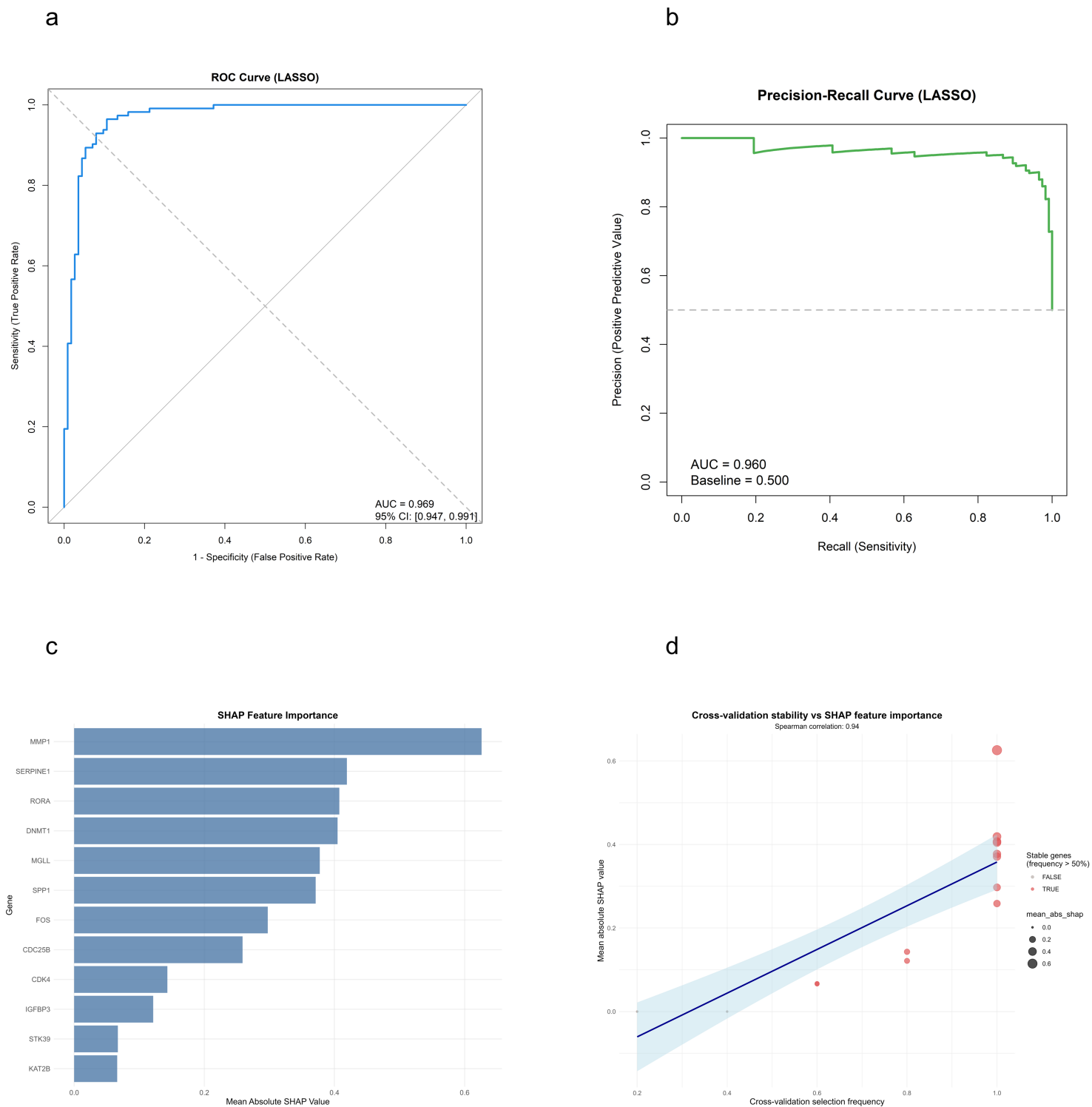


Figure S5. Performance evaluation of the LASSO model and SHAP-based feature interpretability analysis. **(a)** ROC curve. **(b)** PR curve. **(c)** feature importance bar plot. **(d)** correlation scatter plot of cross-validation stability versus SHAP feature importance for the LASSO model.