Supplementary Materials

From prediction to practice: a narrative review of recent artificial intelligence applications in liver transplantation

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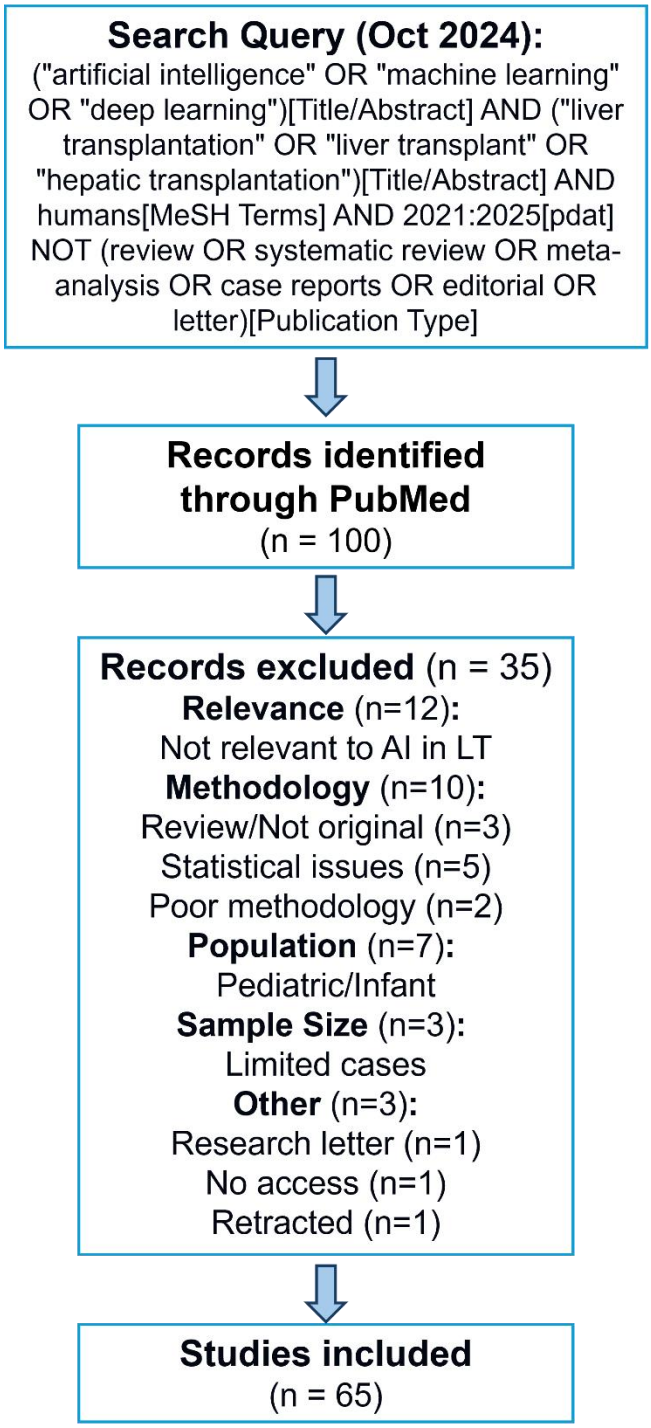

Supplementary Figure 1. Flow Diagram of Study Selection for AI Applications in Liver Transplantation (Jan 2021–Oct 2024)

Figure illustrates the study selection process for AI-related research in LT. From an initial 100 records identified through PubMed, 65 studies met the inclusion criteria after exclusions based on relevance, methodology, population, sample size, and other considerations.

Supplementary Table 1. AI in pretransplant risk assessment

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	Accuracy
Wada et al	PreLT	Extracellular volume fraction (ECV) for liver fibrosis	Images (CT)	Deep learning-based spectral CT using deep learning views (DLVs) generated by a trained neural network	Retrospective, single cente	Segmentation	63	0.891	
Yu H et al	PreLT	Segment liver portal tract regions	Images (Histology)	CNN (Multiple Up-sampling and Spatial Attention guided UNet model (MUSA-UNet))	Retrospective, single center	Segmentation	53		0.89
Ahn JC et al	PreLT	Predicting Cirrhosis vs no cirrhosis	Images (ECG)	CNN	Retrospective, multicenter	None	5212	0.908	
Schuessler M et al	PreLT	Pre-operative coronary artery disease assessment by measuring preop coronary computed tomography angiography-derived fractional flow reserve (CT-FFR)	Images (CT scans)	Neural network for for CT-FFR computation	Retrospective, single center	None	201		0.85

Gerussi A et al	PreLT	Death or need for transplant in primary biliary cholangitis	Tabular	Clustering	Retrospective, multicenter	Rule based	12888		0.789
Azhie A et al	PostLT	Liver fibrosis post LT (>=F2)	Tabular (longitudinal)	Weighted LSTM	Retrospective, single center, longitudinal	Gradients	1893	0.798	
Qazi Arisar FA et al	PostLT	Liver fibrosis post LT (>=F2)	Tabular (Radiomics, Clinical)	LASSO (Least Absolute Shrinkage and Selection Operator	Retrospective, single center	Coefficients	254	0.811	
Mazumder NR et al	PreLT	Liver cirrhosis	Images (CT scan), Tabular	CNN, GBM	Retrospective, single center	Univariate assessment	72	0.84	
Umbaugh DS et al	PreLT	Death or need for liver transplantation for acetaminophen-induced acute liver failure using CXCL14	Tabular	Logistic regression	Retrospective, multicenter	Coefficients	130	0.778	

Supplementary Table 2. AI in donor liver assessment

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	Dice	Accuracy	MAE
Perez-Sanz et al	PreLT	Macrovesicular steatosis in donor liver	Tabular (pixel values)	Naïve Bayes	Retropective, single center	None	20			0.99	
Cherchi el al	PreLT	< 30% HS	Tabular (Photos)	K*	Retrospective, single center		33			0.94	
Jeong el al	PreLT	Living Donor Liver Volume	Images (CT scan)	Deep Attention LSTM U-Net (DALU-Net)	Retrospective, single cente	None	191		0.996		
Lim J el al	PreLT	>5% hepatic steatosis in donor liver biopsy	Tabular	Logistic Regression	Retrospective, single center	Coefficients	1652				
Yang X el al	PreLT	Living Donor Liver Volume	Images (CT scan)	UNETR model (transformer-based deep learning model with a CNN-based decoder)	Retrospective, single center	Not applicable	20		0.959		
Giglio MC el al	PreLT	Graft weight	Tabular	quantile random forest	Retrospective, multicenter	None	872				0.103
Frey KL el al	PreLT	Macrosteatosis greater than 30% in deceased donor liver	Tabular	Logistic Lasso	Retrospective, UNOS	Coefficients	26318	0.71			

Kazami Y el al	PreLT	Segmentatation of liver in living donors	Images (CT scan)	CNN	Retrospective, single center	Not applicable	174		0.9		
Tang H el al	PreLT	Donor liver steatosis	Imaging (histology)	Transformer	Retrospective, single center	not applicable	95			0.96	
Gambella A el al	PreLT	Donor liver steatosis	Images (histology)	CNN	Retrospective, single center	not applicable	292		0.8528		
Oh N el al	PreLT	Segmentation of biliary structure in pure laparoscopic donor hepatectomy	Video	DeepLabV3+	Retrospective, Single center	NA	30		0.728		

Supplementary Table 3. AI in transplant oncology

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	C-Index	Accuracy
He T et al	PostLT	HCC recurrence postLT	Tabular, Images (Histology, MRI)	CNN, MLP	Retrospective, single center	None	109	0.87		
Liu Z et al	PostLT	Recurrence Free Survival (RFS) post HCC resection or LT	Images (Histology), Tabular	CNN classification and segmentation with weak supervised learning	Retrospective, multicenter	None	144			
Huang H et al	PreLT	Malignancy characterization of HCC	Images (MRI)	Denoised local and non-local deep features fusion network	Retrospective, single center	None	107	0.9489		
Kwong A et al	PreLT	3,6,12 months Waitlist dropout for HCC patients	Tabular	Cox Regression	Retropective, UNOS	Coefficients	18920		0.74	
Ivanics T et al	PostLT	PostLT HCC recurrence	Tabular	Regularized Cox Regression	Retrospective, single center	Coefficients	739		0.75	
Liu S et al	PostLT	PostLT HCC recurrence	Tabular	k-top scoring pairs (k-TSP)	Retrospective, single center, longitudinal		128			0.808
Tran BV et al	PostLT	postLT HCC recurrence risk	Tabular	Random Survival Forest	Retrospective, multicenter	Coefficients	6141		0.81	
Qu WF et al	PostLT	HCC Time to recurrence (TTR) and Recurrence-free	Images (Histology)	CNN + attention	Retrospective, single center	Attention Heatmap	380		0.849	

		survival (RFS) postLT								
Iseke S et al	PostLT	HCC recurrence 1-6 years postLT	Images (MRI)	CNN + Xgboost	Retrospective, single center	None	120	0.76		
Altaf A et al	PostLT	5-year recurrence-free survival (RFS)	Tabular	MLP	Retrospective, single center	SHAP	192	0.77		
To J et al	PostLT	HCC recurrence postLT	Tabular (Gene expression)	CNN	Retrospective, single center	SHAP	7			0.8

Supplementary Table 4. AI in graft survival prediction

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	C-Index
Guijo-Rubio et al	PostLT	5 year Graft survival	Tabular	Logistic regression	Retrospective, UNOS	Coefficients	39189	0.654	
Cooper et al	PostLT	Diagnosis of graft vs host disease post LT	Tabular	C5 decision trees	Retrospective, singlecenter	Decision Trees	2013	0.86	
Ding et al	PostLT	Graft failure	Tabular	Tree based, neural networks	Retrospective, UNOS	Ablation study	160360	0.79	
Zalba et al	PostLT	1 year graft survival with role of comorbidities	Tabular	ANN	Retrospective, single center	None	596		0.745
Bambha et al	PostLT	10 year graft survival post nondirected living liver donors (ND-LLD)	Tabular	Random forest survival	Retrospective, UNOS	LIME	6328		0.63
Lin et al	PostLT	Early allograft dysfunction	Tabular (Protein, Metabolites, LFT)	XGBoost	Retrospective, single center	SHAP	223	0.833	
Yanagawa et al	PostLT	90 day Graft failure	Tabular (UNOS)	LGBM	Retrospective, UNOS	None	64384	0.7	

Supplementary Table 5. AI for overall survival prediction

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	C-Index
Yasodhara et al	PostLT	Mortality post LT in DM patients	Tabular	Coxph	Retrospective, UNOS	SHAP	1290		0.61
Nitski et al	PostLT	Cause of death	Tabular (Longtiudinal)	Transformer	Retrospective, multicenter	Saliency	45415	0.804	
Yu et al	PostLT	1 year survival post LT	Tabular	Random forest	Retrospective, multicenter	SHAP	785	0.81	
Yang et al	PostLT	90-day postoperative survival of ACLF patients following liver transplantation	Tabular	Random Forest	Retrospective, single center	Coefficients	371	0.94	
Fonseca et al	PostLT	Mortality post 1 year factoring malnutrition while on waitlist	Tabular	Random Forest	Retrospective, single center	Shap	419	0.8	
Ivanics et al	PostLT	90-day post-LT mortality	Tabular	Ridge regression	Retrospective, multinational	None	66059	0.64	
Ding et al	PostLT	Death due to rejection and infection postLT	Tabular	multitask gradient boosting decision trees	Retrospective, UNOS	None	8922	0.64	
Park et al	PostLT	Overall Survival after newly developed sarcopenia after liver transplantation	Images (CT scan)	3D CNN	Retrospective, single center	None	107		

Ge et al	PostLT	1 year survival post LT for ACLF	Tabular	Combination of gradient boosting machine and lasso followed by manual survey	Multicenter, retrospective	Rule based	1384	0.719	
Rogers et al	PostLT	Overall Survival	Tabular	Logistic regression, SurvCART	Retrospective, UNOS	Coefficints, Tree based	122134	0.742	
Liu et al	PostLT	Survival of patients with HCC post resection /LT using sarcopenia	Imaging (CT) + Tabular	Deepsurv, autoencoder	Multicenter, retrospective	None	173		0.653

Supplementary Table 6. AI in immunosuppression management

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	MAE	RMSE
Ponthier L et al	PostLT	Tacrolimus AUC estimation	Tabular	MARS	Retrospective, multicenter	Feature Importance	161		0.0986
Li et al	PostLT	Tacrolimus concentration	Tabular	XGBoost	Retrospective, singlecenter	None	177		3.5
Du et al	PostLT	Steady-state trough concentration (C0) of tacrolimus post liver transplant	Tabular	MLP	Retrospective, singlecenter	SHAP	31	0.6	
Yoon et al	PostLT	Tacrolimus concentration	Tabular	LSTM	Retrospective, multicenter	SHAP	443	0.22	

Supplementary Table 7. AI for post-transplant risk predictions

Authors	Stage	Prediction Task	Independent variables	Algorithms	Study Design	Interpretation	Number of LT patients	AUC	Accuracy	MAE
Zhang et al	PostLT	Acute Kidney Injury (AKI) post LT	Tabular	GBM	Retrospective, single cente	SHAP	894	0.75		
He et al	PostLT	Acute Kidney Injury (AKI) post LT	Tabular	Random Forest	Retrospective, single cente	Gini Cofficient	493	0.85		
Chen et al	PostLT	Pneumonia post LT	Tabular	recursive feature elimination + XGB	Retrospective, single cente	Feature Importance Plot	591	0.794		
Jain et al	PostLT	Major Adverse Cardiovascular Event (MACE)	Tabular	XGBoost	Retropective, single center	SHAP	1459	0.71		
Lee et al	PostLT	Harmful alcohol use post-LT	Tabular	XGboost	Retrospective, multicenter	Gini coefficient	116	0.692		
Freire et al	PostLT	Carbapenem-resistant Enterobacterales carriage at liver transplantation	Tabular	Random Forest	Retrospective, multicenter	SHAP	1544	0.83		
Chen et al	PostLT	Postoperative sepsis within 7 days after liver transplantation	Tabular	Random Forest	Retrospective, single center	SHAP	786	0.755		
Cheng et al	PostLT	Predicted Age Difference (PAD) in LT patients considering the impact of preoperative hepatic encephalopathy	Images (MRI)	CNN	Retrospective, single center	None	60			3.16

Zaver et al	PostLT	De novo post-transplant AF and low left ventricular ejection fraction	Images (ECG)	CNN	Retrospective, single center	None	300	0.69		
Li et al	PostLT	Malignancy, diabetes, rejection, infection and cardiovascular complications post LT and fairness	Tabular	Transformer	Retrospective, UNOS	Permutation-based	160360	0.7		
Fodor et al	PostLT	PostLT Biliary compications	Images (hyperspectral imaging), Tabular Data	CNN	Retrospective, Single center	None	14		0.94	
Jang et al	PostLT	30-day major cardiovascular event	Tabular	Multivariate logistic analysis, extreme gradient boosting algorithm, Shapley additive explanation scores (SHAP)	Retrospective, Single center	SHAP	4148			