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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐ A description of all covariates tested
☐	☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☐	☒ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Dicom files were handled with the open source libraries Pydicom (https://pydicom.github.io/, version 2.2.2), simplelTk https://simpleitk.org/, version 2.0.2), and jinglingbaiozhu (http://www.jinglingbiaozhu.com/, version 2.0.4). Custom Python (version 3.9.7) script was developed for data processing.
Data analysis	All data analysis was perfprmed using Python 3.9.7. The packages or softwares comprised Pytorch 1.12.1 for model training and testing, CUDA 11.4 and cuDNN 8.2.4 for GPU acceleration, and scikit-learn 1.1.3 for statistical analysis. Our system architecture incorporates innovative technologies, including the YOLOv8 model for lesion detection, the 3D U-Net segmentation model for postprocessing, and our proposed LiLNet classification model. To maintain transparency and reproducibility, we offer access to the source code and models for each component through open-source platforms. The respective repositories are as follows: YOLOv8 can be found at https://github.com/ultralytics/ultralytics; the hyperlinks for 3D U-Net is https://github.com/ellisdg/3DUnetCNN; and the hyperlink for ReNet50 is https://github.com/weiaicunzai/pytorch-cifar100/blob/master/models/resnet.py. In addition, our system's complete custom code can be found at https://github.com/yangmeiyi/Liver/tree/main.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All the analytical data underpinning the findings of this study are incorporated within this paper in the designated source data files (Source_data_Figure_2.xlsx to Source_data_Figure_6.xlsx and Source_data_Table_2.xlsx to Source_data_Table_3.xlsx). However, the original dataset used in this study is subject to access control, requiring licenses from multiple central institutions for access. The author of the article communicated with several hospital departments, including the Information Technology Department, Research Laboratory, and International Cooperation Office. Although these data do not involve blood or other biological samples, the hospital's strict data management policy prohibits any external sharing of research data. These regulations aim to ensure that all data, regardless of its nature, are securely protected to prevent unauthorized use or disclosure. To promote further international cooperation and exchange, it is recommended to jointly apply for international multicenter cooperation projects. This approach will enable us to conduct further research within the hospital while ensuring compliance with hospital policies, data security, and patient privacy. For academic inquiries regarding the use and processing of raw data, please contact the corresponding author via email at cjr.songbin@vip.163.com or csmliu@uestc.edu.cn.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	We have provided the gender and age of the participants. Gender and Age assignment was based on government-issued IDs. The datasets utilized in the internal training and test cohorts, as well as the external multi-center test cohorts, have reported sex distributions as outlined in the paper. No sex-based analysis was conducted as gender was unrelated to the model implementation or deployment. The primary reason for this is that the focus of our study was on evaluating the technical performance of the system, rather than examining potential differences based on gender or sex. Additionally, our primary objective was to ensure the system's accuracy and efficiency in processing imaging data, regardless of the patient's gender.
Reporting on race, ethnicity, or other socially relevant groupings	We are using only retrospective data collected through clinical practice. Race, ethnicity, and other socially relevant groupings were not collected from the patients and were unrelated to model implementation or deployment.
Population characteristics	This retrospective study included five patient cohorts: an internal training cohort , an internal test cohort, four external validation cohort, and two real-world clinical test cohort. The distribution of age and sex in the training set is as follows: For HCC, the female-to-male ratio is 155 to 548, with an average age of 53.06 years (±11.90). In ICC, there are 157 females and 166 males, with an average age of 57.16 years (±12.10). MET have 70 females and 79 males, with an average age of 55.07 years (±14.37). FNH cases show a ratio of 59 females to 41 males, with an average age of 35.12 years (±13.49). HEM cases have 84 females and 48 males, with an average age of 50.13 years (±15.63). Finally,CYST are represented by 77 females and 96 males, with an average age of 58.53 years (±12.93). The distribution of age and sex in the internal test set is as follows: For HCC, there are 196 females and 750 males, with an average age of 52.34 years (±12.69). In ICC, there are 43 females and 37 males, with an average age of 57.27 years (±12.28). MET have 60 females and 73 males, with an average age of 56.24 years (±13.44). FNH cases show a ratio of 19 females to 16 males, with an average age of 33.65 years (±13.21).HEM cases have 33 females and 30 males, with an average age of 47.96 years (±11.06). Finally, CYST are represented by 23 females and 28 males, with an average age of 56.66 years (±12.36). In the validation set from Henan Center, the distribution of age and sex is as follows: For HCC, there are 42 females and 259 males, with an average age of 55.56 years (±10.34). In ICC, there are 18 females and 26 males, with an average age of 59.29 years (±10.38). MET have 39 females and 59 males, with an average age of 58.61 years (±12.89). FNH cases show a ratio of 20 females to 19 males, with an average age of 35.46 years (±15.22). HEM cases have 63 females and 31 males, with an average age of 50.77 years (±10.71). Finally, CYST are represented by 31 females and 29 males, with an average age of 59.13 years (±11.12). In the validation set from Chengdu Center, the distribution of age and sex is as follows: For HCC, there are 20 females and 74 males, with an average age of 59.79 years (±12.20).In the validation set from Guizhou Center, the distribution of age and sex is as follows: For HCC, there are 31 females and 142 males, with an average age of 54.04 years (±11.00). For ICC, there are 23 females and 20 males, with an average age of 59.18 years (±11.70). In the validation set from Leshan Center, the distribution of age and sex is as follows: For HCC, there are 21 females and 135 males, with an average age of 57.5 years (±10.88). For ICC, there are 31 females and 18 males, with an average age of 59.92 years (±12.14).
Recruitment	Between Jun 2012 and December 2022, a total of 4039 patients' multi-phase contrast-enhanced CT images (Arterial Phase and Portal Venous Phase) from six centers in China were included with the following inclusion criteria: (1) patients were eighteenyears older; (2) patients do not have a history of hepatectomy, transarterial chemotherapy (TACE), radiofrequency ablation (RFA) before the CT examination; (3) Malignant tumors were pathologically confirmed; (4) Benign tumors were confirmed either by consensus among three radiologists or by follow-up of at least six months using two imaging modalities; Furthermore, clinical testing was conducted on two real-world clinical evaluation queues: West China Tianfu Center and Sanya People's Hospital. At Tianfu Center, we examined 184 cases, while at Sanya People's Hospital, 235 cases were assessed.
Ethics oversight	Ethics committee approval was granted by the ethics review board of West China Hospital of Sichuan University (Ethical Approval No. 2024-424), and was carried out in adherence to the Declaration of Helsinki. Additionally, this study is officially registered with the Chinese Clinical Trial Registry, under the identifier ChiCTR2400081913 (accessible at https://www.chictr.org.cn/showproj.html?proj=212137). Recognizing the non-invasive nature of the methodology and the

anonymization of data, the institutional review boards granted a waiver for the informed consent requirement. Subject to data privacy and confidentiality, ethical review, and institutional policies, we use patient imaging data solely for system testing without requiring the patient to undergo additional testing, visits, or any activities directly related to the system. Under these conditions, generally, no additional compensation to the patient is necessary.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	No statistical method was used to determine the sample size. In this retrospective analysis, we incorporated 4039 patients, comprising 3293 malignant tumors and 746 benign tumors, collected from six data centers to develop the liver lesion diagnosis system LiLNet. The study recruited 2888 patients from West China Hospital of Sichuan University and Sanya People's Hospital in China for training and testing. Furthermore, we enrolled an additional 1151 patients for external validation, sourced from Henan Provincial People's Hospital, The First Affiliated Hospital of Chengdu Medical College, Guizhou Provincial People's Hospital, and Leshan People's Hospital in China. We trained the LiLNet model to differentiate hepatic tumors using CT screening images from West China Hospital of Sichuan University and Sanya People's Hospital. For the diagnosis of benign and malignant tumors, our training set comprised 1423 patients, consisting of 418 benign and 1005 malignant patients, while testing set included 1465 patients, with 135 benign and 1,330 malignant patients. For the subtype classification, the training dataset consisted of CT images from 1580 patients at two Centre, including 703 HCC, 323 ICC, 149 MET, 120 HEM, 133 CYST, and 100 FNH patients. The testing dataset included CT images from 1308 patients, with 946 HCC, 80 ICC, 133 MET, 35 HEM, 63 CYST, and 51 FNH. Based on the clinical diagnostic consensus, HCC, ICC, and MET were classified as malignant tumors, while HEM, FNH, and CYST were classified as benign tumors.
Data exclusions	According to our inclusion criteria, data from West China People's Hospital excluded 31 patients lacking CT/AP/PVP images, 646 patients with low-quality images, 72 patients with postoperative images, 195 patients with liver lesions not observed through AP and PVP phases, and 178 patients with mismatched target detection frames and lesions. For the four external validation centers, 20 patients lacking CT/AP/PVP images, 64 patients with low-quality images, and 22 patients with postoperative images were excluded. Additionally, through AP, 95 patients did not exhibit liver lesions in the PVP phase, and 114 patients did not match the target detection frame and lesions.
Replication	All attempts at replication were successful.The performance of LiLNet was consistent across the internal center and 4 external centers, quipment manufacture (GE,Philips, Siemens, and United Imaging CT scanners), and application scenarios (emergency department,inpatient department, and outpatient department).
Randomization	In this study, the determination of sample size varies depending on the characteristics of the experiment: for malignant lesions, we followed the principles of machine learning domain partitioning, using a 1:1 random split between training and testing sets to ensure that the testing set accounted for at least 30% of the total data. For benign lesions, we employed a 4:1 random split between training and testing sets to ensure that the training set comprised 80% of the total data, while retaining 20% of the data for objective evaluation of the model. This ratio is widely utilized in machine learning to effectively balance model performance and generalization ability.
Blinding	The investigators were blinded to group allocation during data collection and analysis.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☐	☒ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Clinical data

Policy information about clinical studies

All manuscripts should comply with the ICMJE guidelines for publication of clinical research and a completed CONSORT checklist must be included with all submissions.

Clinical trial registration	This study has received approval from the Institutional Review Board of West China Hospital, Sichuan University and was carried out in adherence to the Declaration of Helsinki. The retrospective component of this study is officially registered with the Chinese Clinical Trial Registry, under the identifier ChiCTR2400081913
Study protocol	https://www.chictr.org.cn/showproj.html?proj=212137
Data collection	1. Locations: Department of Radiology, West China Hospital, Sichuan University, Chengdu, Sichuan, China; collection period: December 1, 2021 to June 28, 2022. 2. Locations: Department of Radiology, Sanya People's Hospital, Sanya, China; collection period: March 1, 2022 to June 28, 2022. 3.Locations: Department of Radiology, Henan Provincial People's Hospital, Zhengzhou, Henan, China; collection period: December 15, 2021 to June 28, 2022. 4. Locations: Department of Radiology, The First Affiliated Hospital of Chengdu Medical College, Chengdu, Sichuan, China; collection period: March 1, 2022 to May 1, 2022. 5. Locations: Department of Radiology, Leshan People's Hospital, Leshan, Sichuan, China; collection period: March 1, 2022 to May 1, 2022. 6. Locations: Department of Radiology, Guizhou Provincial People's Hospital, Guiyang, Guizhou, China; collection period: March 1, 2022 to May 1, 2022.
Outcomes	Primary Outcome Measure: We evaluated the prediction model using statistical measures such as ACC, sensitivity, specificity, precision, recall, F1-score (f1), AUC, and receiver operator characteristic (ROC) curve.

Plants

Seed stocks	Not applicable
Novel plant genotypes	Not applicable
Authentication	Not applicable