

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
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ | 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
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ | 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	NICT simulation using ASTRA Toolbox (v2.1.2) and ODL (v1.0.0). CT reconstruction using TIGRE (v2.6) in MATLAB (R2022b). Image registration using Elastix (v5.1.0).
Data analysis	TAMP model implemented in PyTorch (v2.10.0) with Python 3.10.13 and CUDA 12.8. Code: https://github.com/YutingHe-list/TAMP

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](#)

SimNICT dataset: <https://huggingface.co/datasets/YutingHe-list/SimNICT> (derived from 10 public CT datasets). Clinical data from NJDTH restricted due to patient privacy (ethics: AF/SC-08/03.0, 2025-0068-02).

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	Sex information obtained from source datasets (self-reported or medical records). Both male and female subjects included. No sex-based analysis performed as CT image enhancement is independent of biological sex.
Reporting on race, ethnicity, or other socially relevant groupings	Not applicable. Race, ethnicity, and other socially relevant variables were not collected as this study focuses on CT image enhancement algorithms, which are independent of such demographic factors.
Population characteristics	Pre-training: 9,638 subjects from 10 public datasets. Real-world validation: NJDTH-A (6 patients, 1 male/5 females, aged 49-79), NJDTH-B (10 patients, 9 males/1 female, aged 44-76), NJDTH-C (6 patients, 5 males/1 female, aged 43-79), Mayo (10 patients, public dataset). Detailed demographics available in public source datasets.
Recruitment	Public datasets from open repositories (no recruitment). Clinical data retrospectively collected from routine CT scans at Nanjing Drum Tower Hospital Jiangbei. Multi-source datasets used to ensure generalizability.
Ethics oversight	Medical Ethics Committee of Gulou Hospital Affiliated to Nanjing University Medical School (AF/SC-08/03.0, 2025-0068-02)

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	Pre-training: 9,638 subjects (no statistical predetermination; 360× larger than existing works, sufficient for foundation model). Simulated validation: 125 subjects. Real-world validation: 32 patients. Sample sizes following related works.
Data exclusions	Low-quality CT volumes excluded before pre-training via manual inspection. 9,638 volumes retained from 10,563 original volumes.
Replication	All experiments reproducible. Code: https://github.com/YutingHe-list/TAMP . Data: https://huggingface.co/datasets/YutingHe-list/SimNICT . Model weights available in repository.
Randomization	Training/testing sets randomly split (80%/20%). Validation datasets independent from pre-training data. NICT simulation parameters randomly sampled within defined ranges.
Blinding	Radiologist validation blinded to image source and enhancement method. Quantitative evaluation used objective metrics (PSNR, SSIM, etc.), blinding not applicable.

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	Not applicable. This is a retrospective deep learning study with no patient intervention.
Study protocol	Not applicable (not a clinical trial). This is a deep learning study using retrospective CT data. Ethics: AF/SC-08/03.0, 2025-0068-02. Informed consent waived.
Data collection	Public datasets from open repositories. Clinical data from Nanjing Drum Tower Hospital Jiangbei. Mayo data from 2016 Low Dose CT Grand Challenge.
Outcomes	Primary: image quality metrics (PSNR, SSIM, RMSE, LPIPS) computed automatically. Secondary: clinical acceptability (PBN, SQR, PCA) assessed by 3 blinded radiologists via ranking and scoring.

Plants

Seed stocks	No plants were used in this study.
Novel plant genotypes	No plants were used in this study.
Authentication	No plants were used in this study.