

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 (<i>n</i>) 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. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> 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 <i>d</i> , Pearson's <i>r</i>), 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	Python 3.9.16 (Python Software Foundation), MATLAB 2021b (MathWorks, Inc.), Fiji 1.53t (National Institutes of Health, USA)
Data analysis	Data constructions were performed using custom Matlab (R2021b,MathWorks) scripts. The deep-learning model reported in this work was implemented with Python 3.9.16 (Python Software Foundation) and PyTorch 1.9.0 (The Linux Foundation). Visualization of the lifetime data, orthogonal views were obtained using Fiji 1.53t (National Institutes of Health, USA) and SPCImage (Becker & Hickl GmbH).

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](#)

The main data supporting the findings of this study are available within the paper and its Supplementary Information. The training and testing data for reproduction are publicly available at <https://doi.org/10.5281/zenodo.10800599>. All data used in this study are available from the corresponding author upon reasonable request.

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	All tissue sections used in this study were obtained after the complete de-identification of any patient-related information. Sex/gender were not considered in study design.
Reporting on race, ethnicity, or other socially relevant groupings	There are no socially constructed or socially relevant categorization variables used directly in the context of the research. The research focuses on technical advancements in fluorescence lifetime imaging microscopy and does not involve human subjects research that would typically require consideration of such variables.
Population characteristics	All tissue sections used in this study were acquired after de-identifying patient-relevant information and were prepared from residual specimens. Consequently, our research did not disrupt standard care practices or sample collection procedures.
Recruitment	Physicians and surgeons were responsible for patient recruitment and obtaining informed consent. Utilizing de-identified residual tissue specimens that were previously archived, we conducted our experiments.
Ethics oversight	The procedures and protocols conducted in this study received approval from Medical Ethics Committee, Shenzhen University Medical School (PN-202300128).

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](https://www.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	The sample size (n) of each experiment is provided in the figure legends in the main manuscript and supplementary information files.
Data exclusions	No data were excluded.
Replication	The number of repetitions for each experiment is provided in the figure legends in the main manuscript and supplementary information files.
Randomization	Random division of images into training and testing sets was performed.
Blinding	Not relevant, as there were no such experimental groups in this study.

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	Medical Ethics Committee, Shenzhen University Medical School (PN-202300128)
Study protocol	The procedures and protocols, followed for the study and provides some context on ethical considerations, are available from the corresponding author upon reasonable request.
Data collection	Physicians and surgeons were responsible for patient recruitment and obtaining informed consent. Utilizing de-identified residual tissue specimens that were previously archived, we conducted our experiments.
Outcomes	The quality metrics, including correlation, 3D SNR, and SSIM were calculated between the input or output lifetime trace, as described in Methods section.

Plants

Seed stocks	N/A
Novel plant genotypes	N/A
Authentication	N/A