nature portfolio

Corresponding author(s): Guosheng Song

Last updated by author(s): May 23, 2024

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	Transmission electron microscopy (TEM) and energy dispersive X-ray (EDX) analysis are performed by JEM-2100F (JEM-2010, JEOL, Japan) with an accelerating voltage of 200 kV. Dynamic light scattering (DLS) measurements are performed on a Zetasizer Nano ZS90 (Malvern) with a 90° scattering angle and a He-Ne laser. The absorbance is measured by UV-vis spectrophotometer (UV-1800, Shimadzu). Fluorescence spectra and afterglow luminescence spectra are collected by Edinburgh Instruments F-S5 fluorescence spectrometer. The transverse relaxation time is measured on a Bruker Minispec analyzer (60 MHz, Bruker, Germany). X-ray diffraction (XRD) measurement is performed on a XRD6100 (Rigaku) X-ray diffractometer. X-ray photoelectron spectroscopy (XPS) analysis is conducted on Thermo Scientific K-Alpha (ThermoFisher Scientific, USA). Fourier-transformed infrared (FTIR) spectroscopy is performed using a Fourier Transform Infrared Spectrometer (FOLI20). Magnetic resonance imaging and mapping imaging are performed with a 7T MRI scanner (Pharma Scan 70/16 US, Bruker). Afterglow luminescence and fluorescence imaging of solution or animal are performed using an IVIS Lumina XR imaging system under bioluminescence (no excitation) and fluorescence modes, respectively. The amount of metallic element is measured by inductively coupled plasma-mass spectrometry (ICP-MS, 8900, Agilent). Radiation treatment is arranged using RS 2000 Small Animal Irradiator.
Data analysis	Living Image® software (IVIS imaging systems) was used to analyze afterglow signal and fluorescence data. Para Vision 360 software was used to analyze MRI signal data. Image J software was used to subtract MRI images and analyze subtraction MRI data, immunofluorescence data, and wester blotting data. Data representation: Origin2018, Excel.

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 data of this study are available in the main text and its supplementary files. Any additional requests for information can be directed to, and will be fulfilled by, the corresponding authors. Source data are provided with this paper.

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	This study did not involve human research participants.
Reporting on race, ethnicity, or other socially relevant groupings	This study did not involve human research participants.
Population characteristics	This study did not involve human research participants.
Recruitment	This study did not involve human research participants.
Ethics oversight	This study did not involve human research participants.

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	Sample sizes were assigned based upon historical practices, in line with our previous publications, Dual Key Co-activated Nanoplatform for Switchable MRI Monitoring Accurate Ferroptosis-based Synergistic Therapy. Chem, 2022, 8, 956-1981.
Data exclusions	No data was excluded from the analysis.
Replication	All experiments were replicated independently 3-6 times, as indicated in figure legends.
Randomization	Cell sample were randomly allocated to treatment by random division into multi-well plates. animals were randomized by random number.
Blinding	Investigators were not blinded to group allocation during data collection and analysis for both in vitro and in vivo experiments

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

Antibodies

Antibodies used

1. Anti-APE1 antibody,Cat. # ab137708, diluted 1:1000 with 3% BSA, abcam;
2. Tubulin Rabbit Monoclonal Antibody, Cat, # AF1216, diluted 1:1000 with 3% BSA, Beyotime;
3. HRP conjugated Goat Anti-Rabbit IgG (H+L), Cat.# A0208, diluted 1:1000 with 3% BSA, Beyotime;
4. Anti-gamma H2A.X (phospho S139) antibody, Cat.# AF5836,diluted 1:500 with 3% BSA , Beyotime ;
5. Cy3-labeled Goat Anti-Rabbit IgG (H+L), Cat.# A0516,diluted 1:500 with 3% BSA , Beyotime;

Validation

All antibodies were verified by the supplier and each lot has been quality tested.

1. Anti-APE1 antibody,Cat. # ab137708, diluted 1:1000 with 3% BSA, abcam, validated for western blot (WB) and tested to detect in mouse by the manufacturer, https://www.abcam.com/products/primary-antibodies/ape1-antibody-ab137708.html
2. Tubulin Rabbit Monoclonal Antibody, Cat, # AF1216, diluted 1:1000 with 3% BSA, Beyotime, validated for western blot (WB) and tested to detect in mouse by the manufacturer,https://www.beyotime.com/product/AF1216.htm.
3. HRP conjugated Goat Anti-Rabbit IgG (H+L), Cat.# A0208, diluted 1:1000 with 3% BSA, Beyotime, validated for western blot (WB) and tested to detect in mouse by the manufacturer,https://www.beyotime.com/product/A0208.htm
4. Anti-gamma H2A.X (phospho S139) antibody, Cat.# AF5836,diluted 1:500 with 3% BSA , Beyotime, validated for immunofluorescence analysis and tested to detect in mouse by the manufacturer,https://www.beyotime.com/product/AF5836.htm
5. Cy3-labeled Goat Anti-Rabbit IgG (H+L), Cat.# A0516,diluted 1:500 with 3% BSA , Beyotime,validated for immunofluorescence analysis and tested to detect in mouse by the manufacturer,https://www.beyotime.com/product/A0516.htm

Eukaryotic cell lines

Policy information about cell lines and Sex and Gender in Research

Cell line source(s)	HeLa cells and HEK293 cells were purchased from China Type Culture Collection, supplied by the American Type Culture Collection (ATCC).
Authentication	The parental HeLa and HEK293 cell line were authenticated by the American Type Culture Collection (ATCC).
Mycoplasma contamination	The cell line was not tested for mycoplasma contamination.
Commonly misidentified lines (See ICLAC register)	No commonly misidentified cell lines were used.

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals	Nude mice (4 - 6 weeks old) were purchased from Hunan SJA Laboratory Animal Co. Ltd. (Changsha, China). All animals were housed with the light cycle of 12 h: 12 h, ambient temperature at 18-22 degree Celsius, and relative humiditrange betweenl 50-60%.
Wild animals	The study did not involve wild animals.
Reporting on sex	The mice used in the HeLa cancer model were female.
Field-collected samples	This study did not include samples collected from the field.
Ethics oversight	All research complied with all relevant ethical regulations. The animal experiments are conducted following the principles of Laboratory Animal Care and the guidelines of the Institutional Animal Care and Use Committee of Hunan University (SYXK 2022-0007 (Xiang).

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

Plants

Seed stocks	The study did not involve plants
Novel plant genotypes	The study did not involve plants
Authentication	The study did not involve plants