Supplementary Information

Advances and Opportunities in NIR-II Endoscopy: From Diagnosis to Therapeutic Applications

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Supplementary Table S1: Summary of main AI applications in NIR-II biomedical imaging since 2020.

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Ref.	Field	Study feature	Main finding
Zhenhua Hu et al.[1]	NIR-II FMT	Proposed a diffusion-based data augmentation strategy with NIR-II-specific optical guidance to generate diverse synthetic training samples.	Augmentation reduced FID by 56.7% and improved IS by 21.5%, enhancing FMT reconstruction accuracy for tumors in simulation and in vivo.
Dayong Jin et al.[2]	NIR-II fluorescence imaging with light-sheet illumination	Combined light-sheet illumination, time-gated detection, and deep learning for high-contrast, high-resolution 3D volumetric imaging.	Achieved 220 μm axial resolution and 0.45 contrast, resolved 100 μm vessels from 0.07 contrast regions; enabled rapid 3D imaging of vascular networks >1 mm deep within 6 min.
Lining Sun et al.[3]	NIR-II fluorescence imaging with lanthanide-doped nanocrystals	Designed excitation-dependent nanocrystals with switchable visible/NIR-II emission, combined with deep learning to integrate narrow visible emission and deep NIR-II penetration.	Achieved high SNR and narrow emission peak through phantom tissue, showing potential for intelligent optical materials and in vivo information security applications.
Fuchun Chen et al.[4]	NIR-II fluorescence vascular imaging	Proposed an unsupervised attention-GAN with attention loss to translate vascular masks into realistic NIR-II fluorescence vascular images, no paired training data needed.	Outperformed 8 baselines in visual and quantitative metrics, generating high-fidelity synthetic data to solve limited dataset issues in NIR-II imaging.
Ye Tian et al.[5]	NIR-IIa to NIR-IIb image translation	Developed BRCycle-GAN, a CNN trained on only 63 images, to upgrade NIR-IIa images to NIR-IIb quality.	Outperformed prior models in PSNR and cosine similarity, enabling high-quality NIR-IIb imaging without toxic probes and limited training data.
Jun Qian et al.[6]	NIR-II fluorescence volumetric microscopy	Combined ETL with two deep learning networks (SRN for enhancement, CVI for axial interpolation) for rapid 3D deep-tissue vascular imaging.	Achieved 4.2 fps volumetric imaging over 200 μm depth in mouse brain; 16-fold axial upsampling enabled smooth 3D reconstruction and quantitative blood velocity measurement at varied depths.
Jun Qian et al.[7]	NIR-II fluorescence image resolution enhancement	Fine-tuned Real-ESRGAN to overcome detector resolution limits in NIR-II imaging, validated in whole-body vascular, NIR-IIc, and diabetic foot clinical scenarios.	Outperformed bilinear and bicubic interpolation in PIQE and FWHM; generalized to untrained NIR-IIc data (abdomen, intestine, leg), enabling clearer vascular visualization for clinical surgical guidance.
Ye Tian et al.[8]	NIR-II imaging-guided cancer	Designed zwitterionic polymer conjugate for Atezolizumab delivery	Conjugate enhanced tumor accumulation and T cell proliferation,

	immunotherapy	with tumor-targeted release and T cell redox homeostasis restoration; visualized in vivo dynamics via deep learning-enhanced NIR-II imaging.	suppressed colorectal tumor growth/recurrence by alleviating T cell ferroptosis, and prolonged survival in murine models.
Xuechuan Hong et al.[9]	NIR-II imaging-guided siRNA therapy for ischemic stroke	Developed long-circulating YWFC NPs crossing blood-brain barrier for NLRP3 siRNA delivery; integrated deep learning to optimize NIR-II imaging of cerebral infarct penumbra.	Image-guided siNLRP3 delivery enhanced BBB penetration and yielded significant therapy in MCAO mice; deep learning-improved NIR-II imaging achieved superior SNR at 72 h post-stroke.
Zhenhua Hu et al.[10]	NIR-II fluorescence vascular image segmentation	Proposed CALFNet: a context-aware local feature network with UNet-like structure, ResNet encoder, Mamba-based global context module, and feature-enhancement module for low-contrast vessel segmentation.	Outperformed competing methods on NIR-II vascular and retinal datasets, enabling more accurate, robust fine vessel segmentation in low-contrast regions and boosting clinical utility of NIR-II imaging.
Ruichan Lv et al.[11]	NIR-II imaging-guided magnetic nanorobots for precision biomedicine	Developed magnetic nanorobot platform with Fe_2O_3 and rare-earth nanoparticles for NIR-II/MRI/PA multimodal imaging and antibody-magnetic dual targeting; integrated deep learning for NIR-II enhancement and temperature sensing.	Achieved rapid tumor targeting (<5 s) and precise localization; real-time temperature detection (24.6–41.5 °C, R^2=0.973, RMSE=1.50 °C); deep learning enabled simultaneous surgical boundary definition and temperature visualization.
Xiaogang Qu et al.[12]	NIR-II-responsive HOF-based NSC encapsulation for Alzheimer's disease therapy	Designed HOF encapsulated NSCs doped with PCNs; PCNs exhibited catalase/SOD-like activities for oxidative stress resistance, while NIR-II triggered thermal-responsive HOF dissociation for on-demand NSC release.	Encapsulation preserved NSC stemness, reduced transplantation damage and apoptosis; NIR-II-triggered release enhanced cell viability, promoted neurogenesis, and ameliorated cognitive impairment in AD mice.
Lining Sun et al.[13]	Multimodal emission nanocrystals for NIR-II information security	Developed Er^{3+}-based lanthanide nanocrystals with switchable visible/NIR-II emission ratios under 980/808/1535 nm excitation, combined with deep learning for information decoding.	Realized switchable output via varied excitation wavelengths; demonstrated tissue-penetrating visible information storage and decoding using multimodal emissions and deep learning.
Hong bo et al.[14]	NIR-II FMT reconstruction	Proposed DSPGN, a deep system prior graph convolution network with spatial/topological information and attention mechanism for improved FMT morphological reconstruction.	Outperformed existing methods in localization accuracy and shape recovery in simulation and in vivo, showing great potential for NIR-II FMT applications.

Bhargava Rohit et al.[15]	Infrared (IR) spectroscopic imaging	Developed a deep learning framework with IR-SEG (CNN for spatial-spectral segmentation) and IR-REC (GAN for full dataset reconstruction from incomplete spatial-spectral data).	IR-SEG achieved higher accuracy with ~50% fewer features; IR-REC enabled up to 20-fold faster acquisition with minimal loss; single-band IR imaging surpassed diffraction limit in spatial detail.
Jie Tian et al.[16]	NIR-II/fluorescence image denoising	The proposed DEQ-UMamba combines proximal gradient descent and spatial-frequency feature learning to decouple complex noise, utilizing deep equilibrium learning for stable convergence with fewer parameters.	Outperformed state-of-the-art methods on clinical and in vivo datasets with fewer parameters, enabling interpretable noise suppression and high-quality, cost-effective clinical molecular imaging.
Gao Feng et al.[17]	fNIRS-DOT neuroimaging	Developed a model-informed deep learning method combining semi-3D DOT (S3D-DOT) and DCNN to reduce ill-posedness, suppress cardiac/respiratory and random noise, and improve reconstruction accuracy.	Achieved mean SSIM >0.998 in simulations, outperforming conventional ART in accuracy and speed; robust under strong noise and dual-target conditions; validated in phantoms; 3D-DCNN extension enabled accurate time-resolved absorption reconstruction.

FMT: Fluorescence molecular tomography; FID: Fréchet Inception Distance; IS: Inception Score; SNR: Signal-to-noise ratio; GAN: Generative adversarial network; CNN: Convolutional neural network; PSNR: Peak Signal -to-noise ratio; ETL: Electrically tunable lens; NIR-IIa, NIR-IIb, NIR-IIc: Subwindows of the NIR-II region (1,000–1,300 nm, 1,500–1,700 nm, 1700-1880 nm, respectively); PIQE: Perception-based image quality evaluator; FWHM: Full width at half maximum; siRNA: Small interfering RNA; BBB: Blood-brain barrier; MCAO: Middle cerebral artery occlusion; HOF: Hydrogen-bonded organic framework; NSC: Neural stem cell; PCN: Porous carbon nanosphere; SOD: Superoxide dismutase; AD: Alzheimer's disease; DOT: Diffuse optical tomography; DCNN: Deep convolutional encoder-decoder; SSIM: Structure similarity index; ART: Algebraic reconstruction technique. Unless otherwise noted, all works listed above are yet to be clinically validated

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