Optical imaging perspective on the use of indocyanine green in endoscopic skull base neurosurgery

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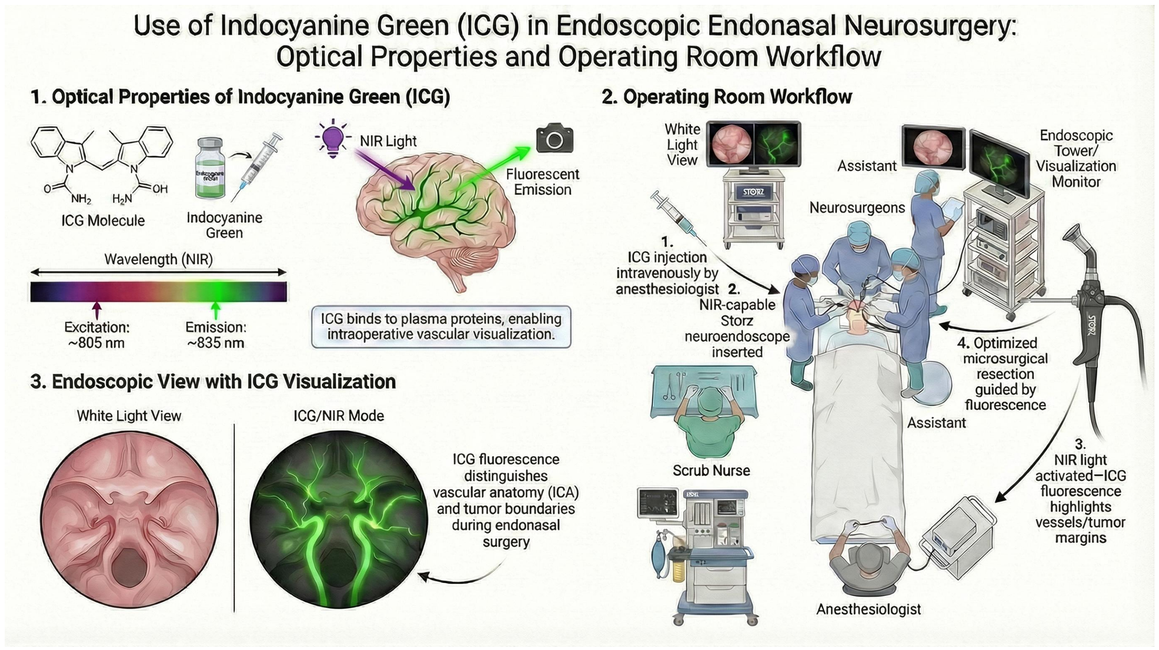
Indocyanine Green: Key Advantages

- Fluorescence-guided surgery (FGS) has become a cornerstone in modern neurosurgery
- Indocyanine green (ICG) stands out given its optical profile
  - excitation/emission in the near-infrared (NIR) spectrum (780 and 805 nm, respectively),
  - deeper tissue penetration
  - favorable signal-to-noise ratios (SNR)
  - excellent safety profiles
- Advances include utilization in endoscopic endonasal skull base neurosurgery (ESS), neurovascular surgery, and 'second-window' ICG

Institutional experience: ICG-endoscopic cases



Case ID	Diagnosis / Variant	Age / Sex	Presentation	Approach	Extent of Resection	ICG Timing	Dose	Timing
1	Rathke cleft cyst	21F	Vision loss + hypercortisolism	Transsellar	GTR	ICG at beginning	6.25 mg	Immediate
2	Pituitary macroadenoma	54F	Acromegaly	Transsellar	Residual in left cavernous sinus	ICG at beginning	6.25 mg	Immediate
3	Pituitary macroadenoma	71 M	Vision loss	Transsellar	GTR	ICG beginning + mid-case to confirm gland	6.25 mg	Immediate
4	Pituitary macroadenoma	79 M	Visual loss	Transsellar	GTR	ICG at beginning	6.25 mg	Immediate
5	Pituitary macroadenoma	49 M	Vision loss	Transsellar + trans-tubercular	GTR	ICG beginning + mid-case for perforator assessment	6.25 mg	Immediate
6	Pituitary microadenoma	64F	Acromegaly	Transsellar	GTR	ICG at beginning	6.25 mg	Immediate
7	Pituitary macroadenoma	68 M	Tumor growth on serial imaging	Transsellar	GTR	ICG at beginning	6.25 mg	Immediate
8	Pituitary macroadenoma	67 M	Hypopituitarism + vision loss	Transsellar	GTR	ICG beginning + during case to identify gland	6.25 mg	Immediate

Intraoperative visualization

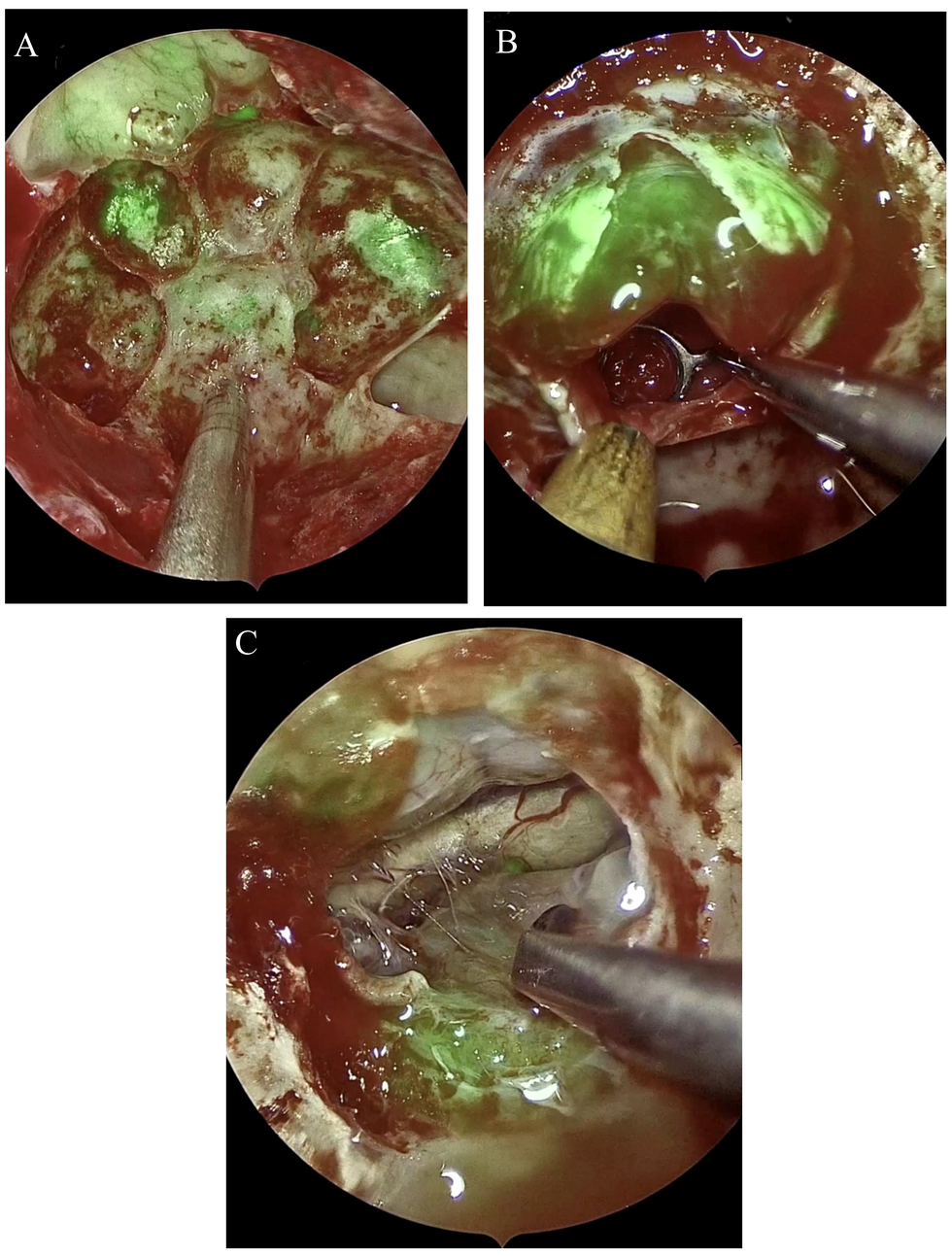


Figure 1: A: ICG imaging of (+) fluorescent internal carotid arteries bilaterally as well as pituitary gland centrally, through the thin skull base; B: ICG imaging of (+) fluorescent pituitary gland, distinctly separating it from the non-fluorescent tumor; C: ICG imaging of (+) fluorescent pituitary and perforator vessels to the optic chiasm

Conclusions

- Integrated workflow of ICG in endoscopic endonasal neurosurgery is efficient and safe
  - Intraoperative dosing regimens and imaging different timepoints can vary to select for key structures or pathology
- Optical properties of NIR light (i.e., low absorption, low scattering) allow high-resolution identification of key neurovascular structures
  - Signal penetration through bone
  - Real-time images of neurovascular structures
- Emerging technologies, such as quantitative fluorescence mapping, and hyperspectral imaging, hold potential to extend ICG use beyond just qualitative visualization

References

1. Roberts DW, Valdés PA, Harris BT, et al. Glioblastoma Multiforme Treatment with Clinical Trials for Surgical Resection (Aminolevulinic Acid). *Neurosurgery Clinics of North America*. 2012;23(3):371-377. doi:10.1016/j.nec.2012.04.001
2. Valdés PA, Roberts DW, Lu FK, PhD, Golby A. Optical technologies for intraoperative neurosurgical guidance. *FOC*. 2016;40(3):E8. doi:10.3171/2015.12.FOCUS15550
3. Cho SS, Salinas R, Lee JYK. Indocyanine-Green for Fluorescence-Guided Surgery of Brain Tumors: Evidence, Techniques, and Practical Experience. *Front Surg*. 2019;6:11. doi:10.3389/fsurg.2019.00011
4. Schupper AJ, Rao M, Mohammadi N, et al. Fluorescence-Guided Surgery: A Review on Timing and Use in Brain Tumor Surgery. *Frontiers in Neurology*. 2021;12. doi:10.3389/fneur.2021.682151
5. Teng CW, Cho SS, Singh Y, et al. Second window ICG predicts gross-total resection and progression-free survival during brain metastasis surgery. *J Neurosurg*. 2021;135(4):1026-1035. doi:10.3171/2020.8.JNS201810
6. Lee JYK, Thawani JP, Pierce J, et al. Intraoperative Near-Infrared Optical Imaging Can Localize Gadolinium-Enhancing Gliomas During Surgery. *Neurosurgery*. 2016;79(6):856-871. doi:10.1227/NEU.0000000000001450
7. Olesrud I, Halvorsen IJ, Storaker MA, Heck A, Dahlberg D, Wiedmann MKH. Indocyanine green fluorescence in endoscopic transsphenoidal resection of pituitary neuroendocrine tumors: a systematic review. *Acta Neurochir*. 2025;167(1):92. doi:10.1007/s00701-025-06500-z

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