NeuVue Perfusion: Geometry-Corrected Quantitative Fluorescence Mapping for Real-Time Assessment of Tissue Viability

Gene Patrick S. Rible, Ph.D.[1]; **Jonathan C. DeLong, M.D.**[2]; Gregory J. Mancini, M.D.[2]; Jindong Tan, Ph.D.[1]

[1]Tickle College of Engineering, University of Tennessee, Knoxville [2]University of Tennessee Medical Center, Knoxville

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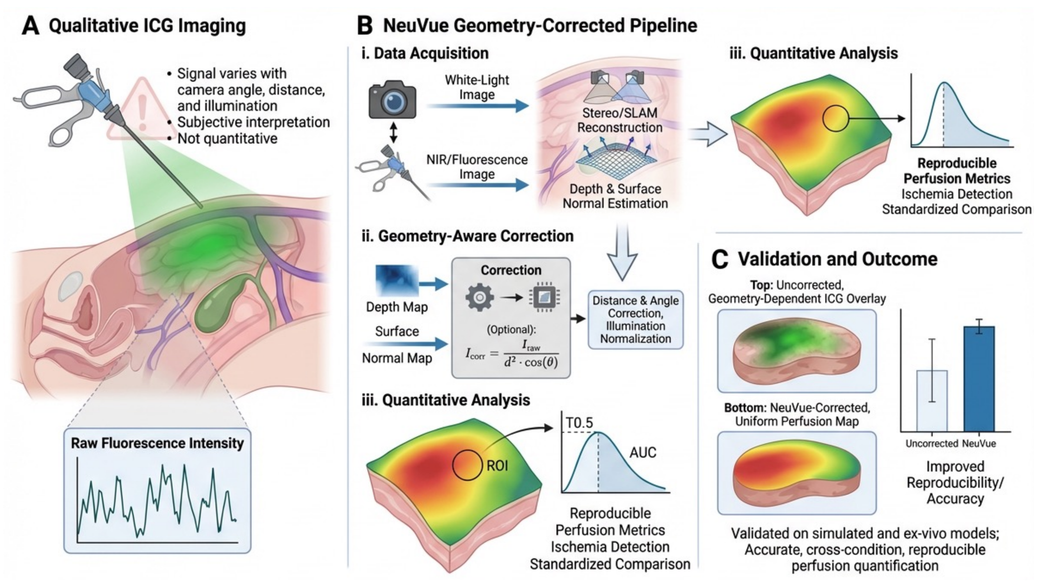
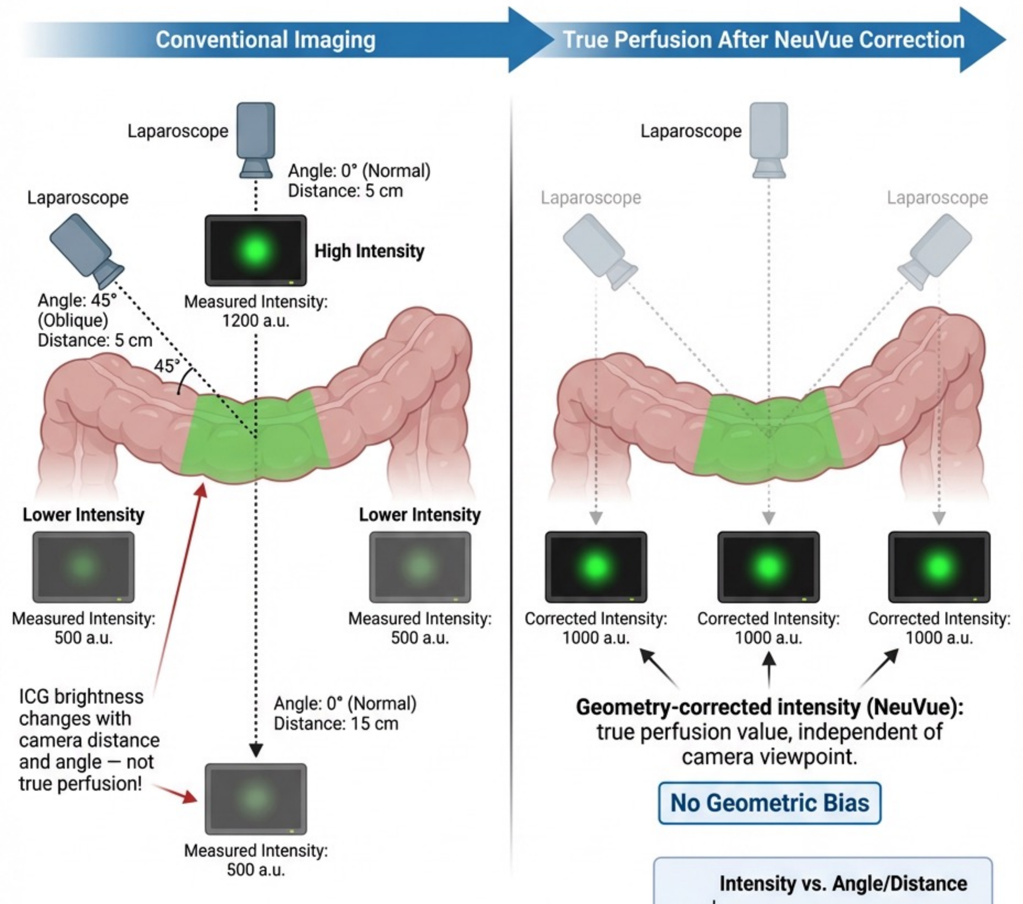
1 OBJECTIVE

Fluorescence angiography with indocyanine green (ICG) has become a standard intraoperative tool for assessing anastomotic perfusion. However, measured brightness is highly dependent on viewing angle, camera distance, and lighting geometry, resulting in subjective interpretation and inconsistent leak-prevention outcomes.



Our Goal

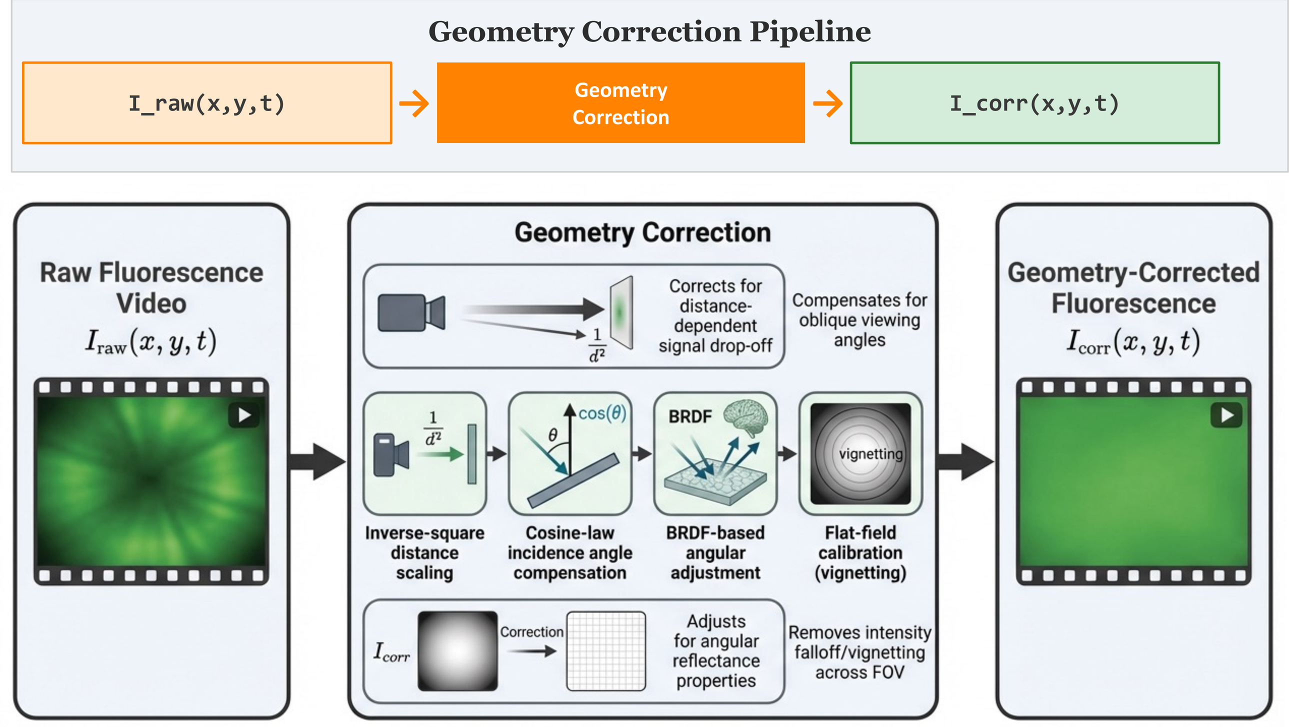
NeuVue Perfusion aims to transform ICG imaging from a qualitative visualization aid into a quantitative, geometry-aware assessment platform that yields reproducible perfusion metrics independent of imaging conditions.



ICG fluorescence brightness is biased by camera distance and viewing angle, causing the same tissue region to appear different in intensity. NeuVue automatically corrects for these geometric factors to reveal the true, quantitative perfusion—enabling accurate, reproducible intraoperative assessment.

2 TECHNOLOGY & METHOD

NeuVue Perfusion integrates stereoscopic imaging and real-time 3D reconstruction within a laparoscopic system to recover per-pixel depth and surface orientation. Using these geometric parameters, the raw near-infrared ICG signal is corrected for inverse-square falloff, incidence angle, and illumination nonuniformity to produce a geometry-normalized fluorescence map.

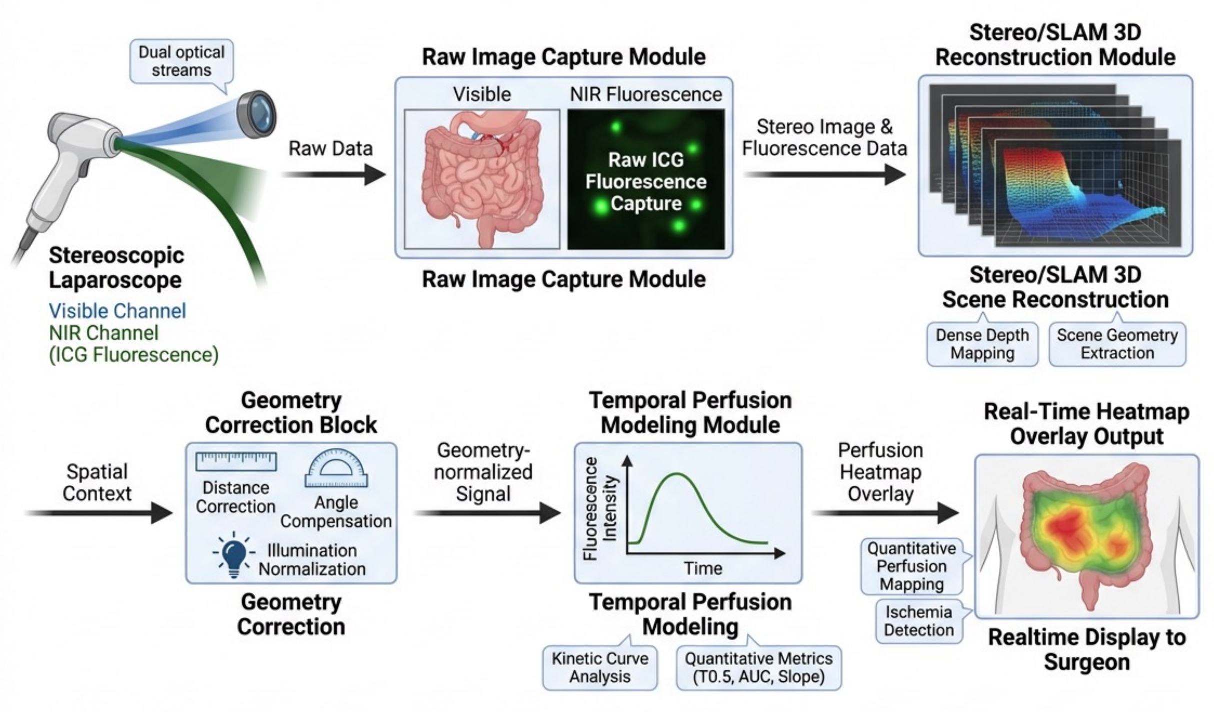


The system operates at 30–60 fps on GPU hardware with sub-100 ms latency during camera motion. Temporal modeling of the corrected fluorescence intensity yields quantitative vascular indices including inflow slope, half-rise time ($T_{0.5}$), and area-under-curve (AUC). These parameters are displayed as perfusion heatmaps that dynamically update during surgery.

30–60 fps	<100 ms	≤2 mm
GPU processing	end-to-end latency	mean depth error

Implemented on the NeuVue platform at the University of Tennessee, integrating optical calibration, photometric correction, and perfusion analysis within a single software pipeline.

NeuVue System Architecture: Multimodal Imaging Pipeline for Quantitative Perfusion Mapping



Visible Channel: Anatomic imaging
NIR Channel: ICG perfusion imaging
3D Reconstruction: Fusion of spatial data
Geometry Correction: Physics-informed normalization
Perfusion Modeling: Temporal analytics
Heatmap Overlay: Quantitative perfusion visualization

3 PROCESSING PIPELINE & RESULTS

NeuVue Perfusion Processing Pipeline

ICG Video → 3D Geometry → Geometry Correction → Perfusion Modelling → Quantitative Heatmaps

Quantitative Perfusion Parameters

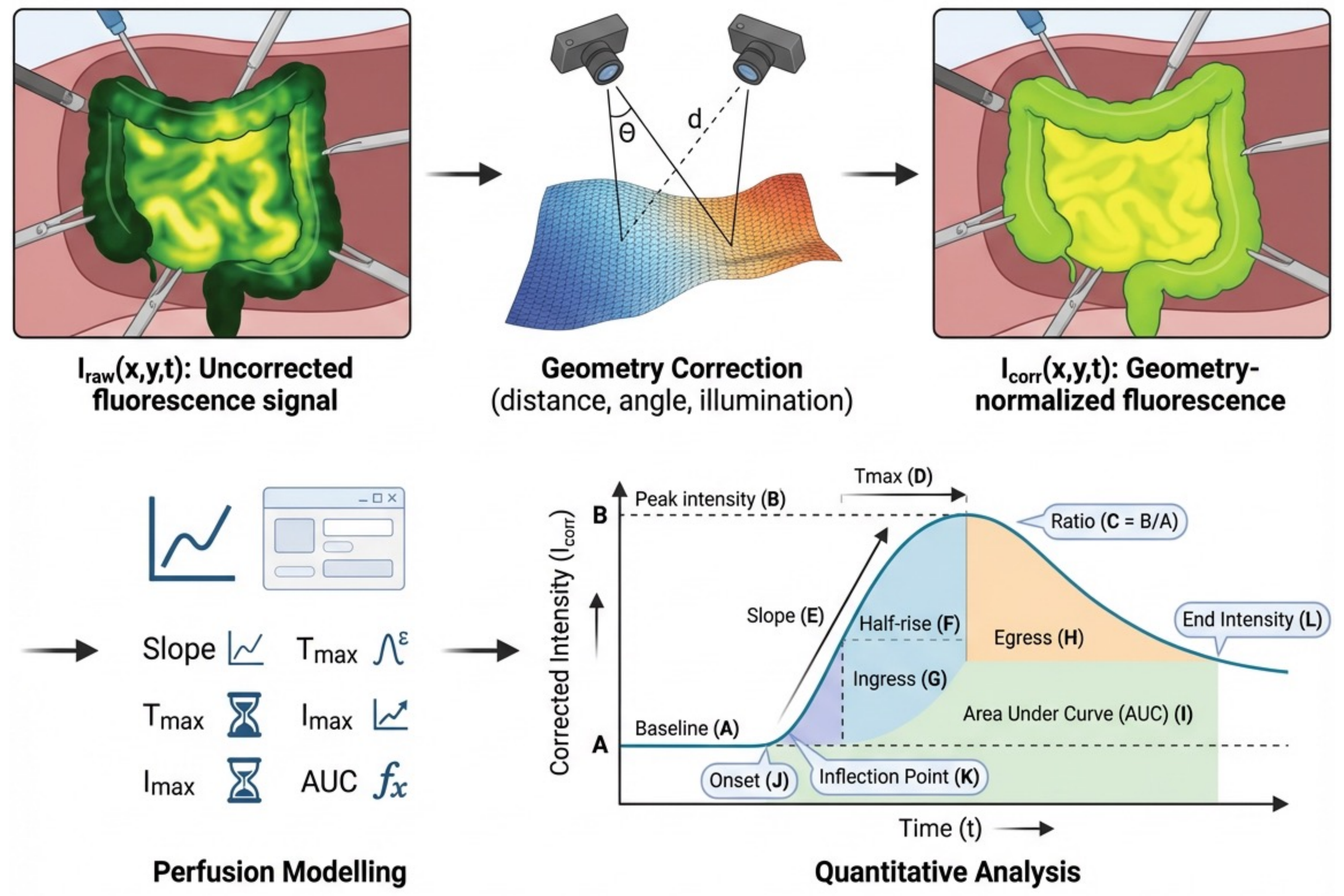
Time-Intensity Curve:

- A: Imax (peak intensity)
- B: Tmax (time to peak)
- C = A/B: Slope (inflow rate)
- I: Baseline intensity
- J: End intensity
- K: Ingress / L: Egress

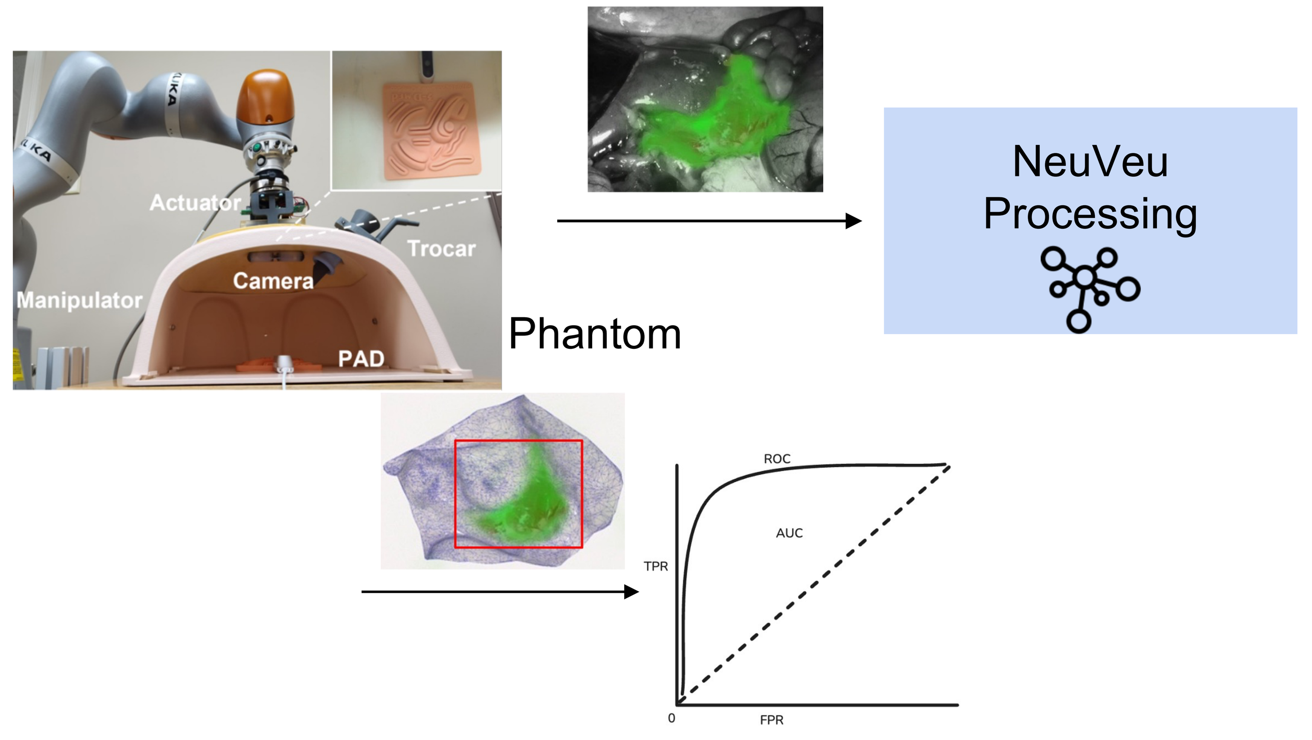
Derived Vascular Metrics:

- Half-rise time ($T_{0.5}$)
- Inflow slope (S_in)
- Time-to-peak (T_p)
- Area-under-curve (AUC)
- Blood flow index (BFI)
- Mean transit time (MTT)

NeuVue Quantitative Perfusion Workflow: From Raw ICG to Geometry-Corrected Metrics



LEGEND: Stereo Camera System; 3D Surface Reconstruction; G H I Curve Areas (G: Ingress, H: Egress, I: AUC); **A-L:** Perfusion Parameters



ICG fluorescence video synchronized with 3D geometry from stereo and SLAM reconstruction is corrected for distance, angle, and illumination, yielding normalized signals. Temporal modeling produces perfusion heatmaps validated on tissue phantoms and simulated anastomosis.

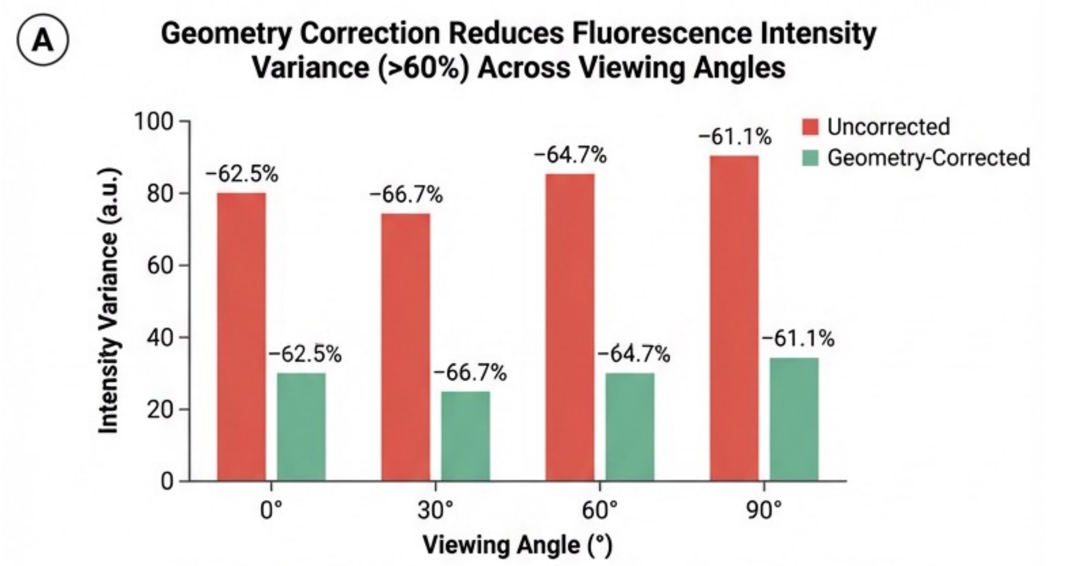
4 PRELIMINARY RESULTS

Benchtop perfusion-phantom experiments demonstrate that geometry correction eliminates angle- and distance-dependent brightness bias, reducing intensity variance by more than 60% compared with uncorrected imaging.

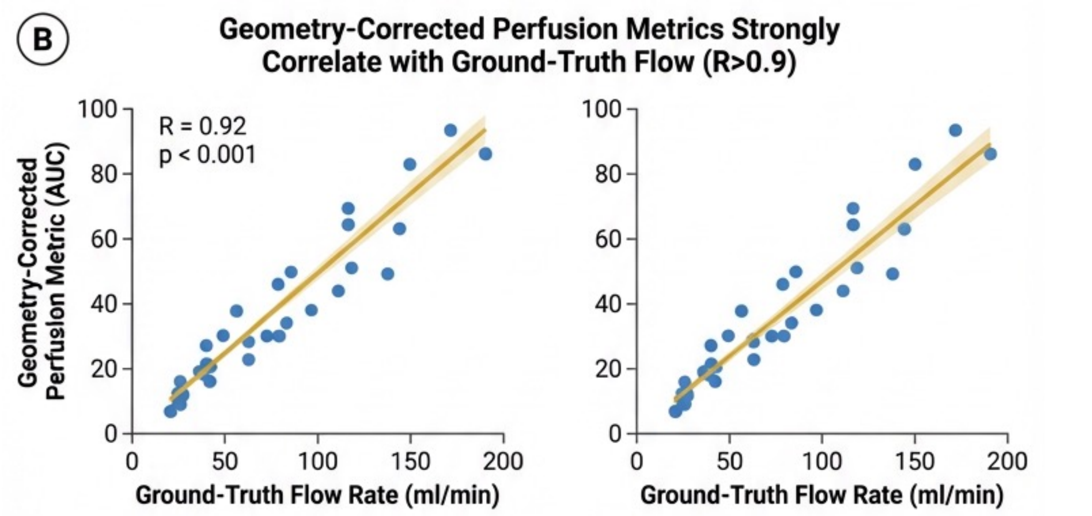
>60%	Reduction in intensity variance	45 fps	Real-time rendering
≤2 mm	Mean depth error	R>0.9	Correlation with ground-truth

Quantitative perfusion curves derived from the corrected signal show strong correlation with ground-truth flow rates in controlled flow-loop tests. Pilot ex-vivo intestinal models confirm that geometry-normalized parameters more accurately identify ischemic regions than conventional raw-intensity analysis.

Validation Tiers: • Benchtop perfusion phantoms • Ex-vivo intestinal anastomosis models • Tissue phantom laparoscopic studies



Correction significantly decreases intensity variance across all angles.



Corrected perfusion metrics show strong linearity with flow rate.

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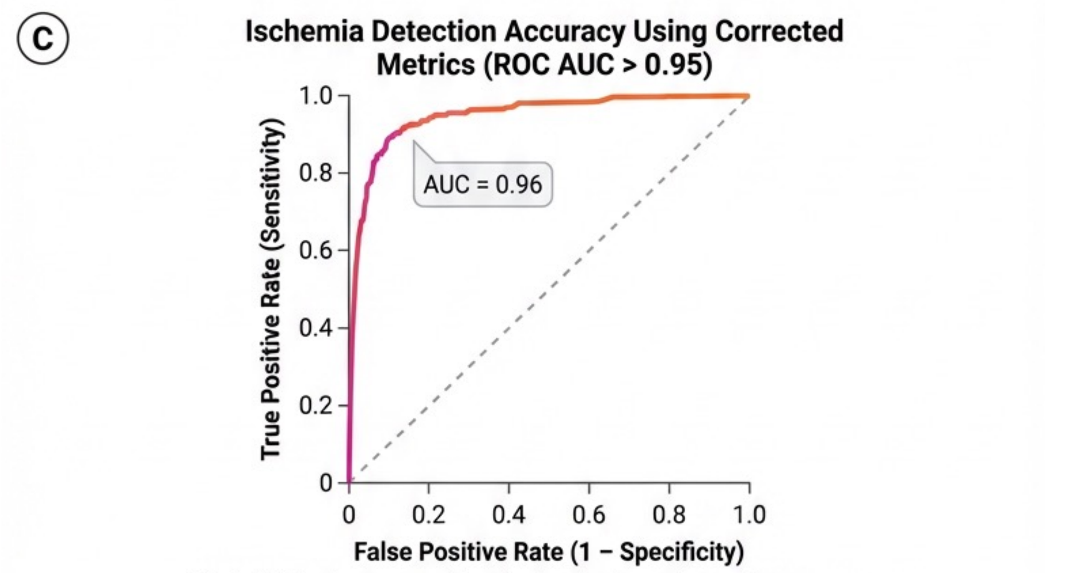


High AUC indicates excellent ischemia detection performance.

5 CONCLUSIONS & FUTURE DIRECTIONS

NeuVue Perfusion establishes a practical, quantitative framework for fluorescence-guided surgery. By decoupling perfusion assessment from optical geometry, it enables standardized, device-independent metrics of vascular adequacy.

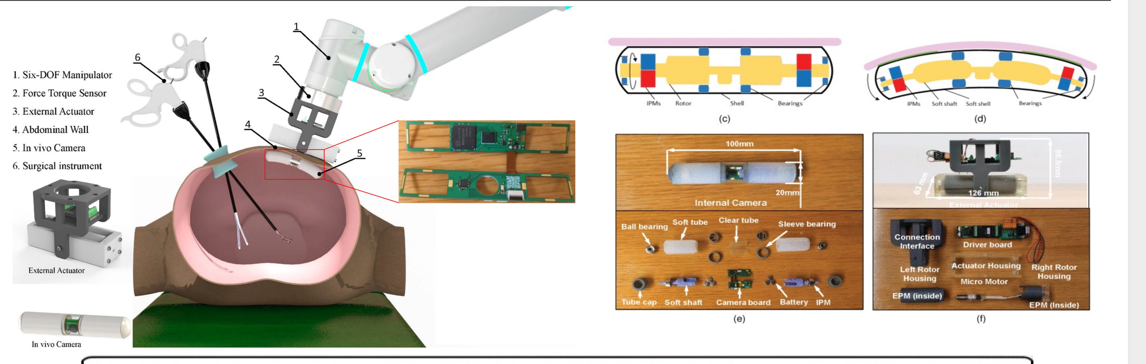
Key Contributions

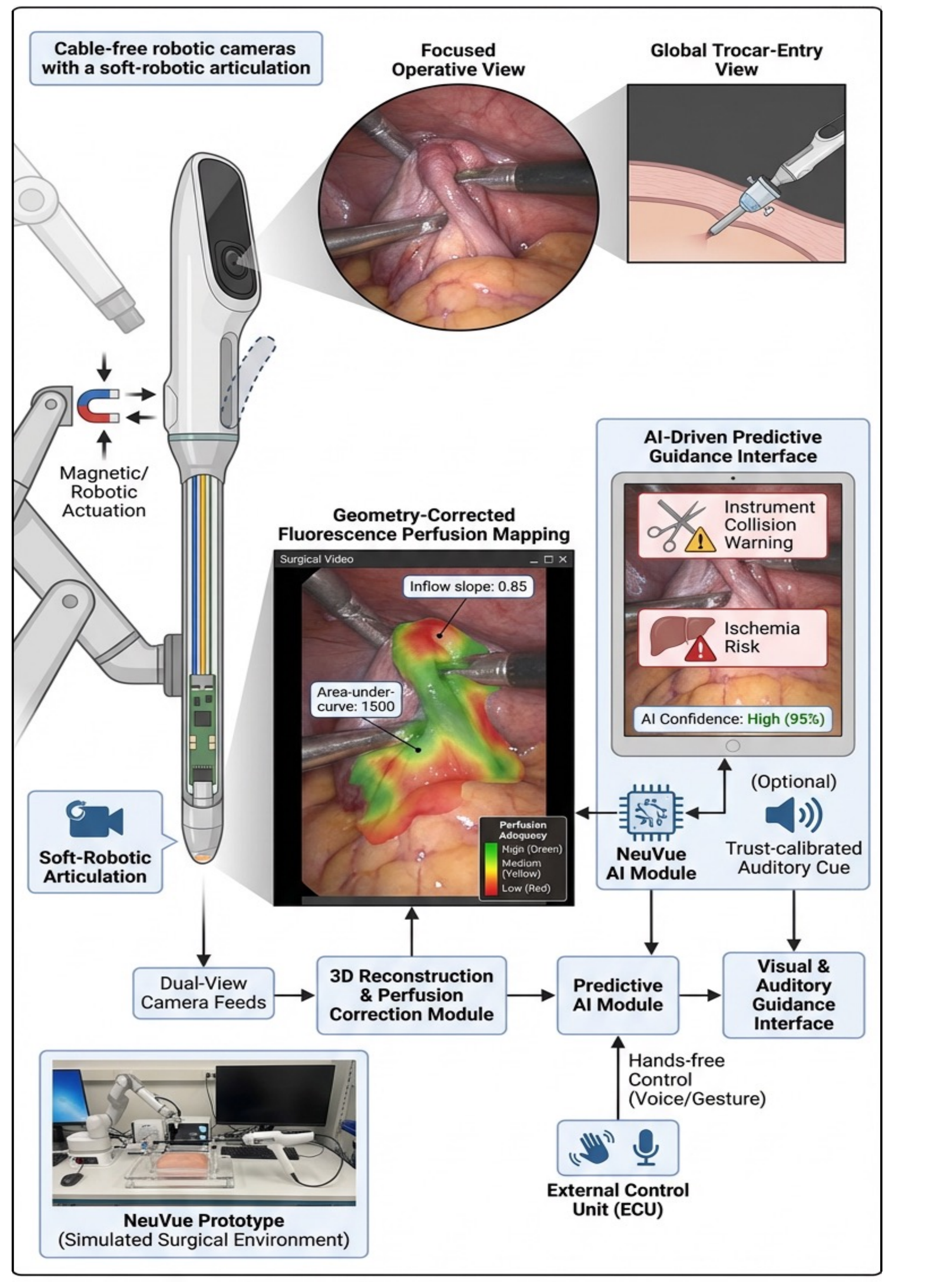
• Geometry-corrected quantitative fluorescence mapping • Device-independent perfusion metrics • Real-time processing (30–60 fps, <100 ms) • Reproducible, objective tissue viability assessment

Future Directions

• Simulated anastomosis model validation • Real-time perfusion overlays with camera systems • Surgical scene understanding • First-in-human feasibility under IRB-approved protocols

This emerging technology provides surgeons with objective, reproducible perfusion feedback that enhances intraoperative decision-making and may ultimately reduce anastomotic leak rates in minimally invasive gastrointestinal surgery.





Conceptual diagram of NeuVue system integration: Robotic dual-view laparoscope, real-time geometry-corrected perfusion mapping, and AI-driven predictive guidance interface in minimally invasive surgery.

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