REVIEW

Artificial Intelligence in the Operating Room: Computer Vision, Anatomy Recognition, and Real-Time Surgical Support

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Published December 2025 · DOI: 10.xxxx/jsi.2025.0005

Abstract. Computer vision and real-time AI assistance are transforming how surgeons interact with anatomy, instruments, and the operative environment. While robotic and image-guided specialties pioneered these systems, plastic surgery and surgery broadly now have access to increasingly sophisticated tools. This article explores the current state of intraoperative AI, its clinical applications, and what surgeons must know before adoption.

Keywords: computer vision, intraoperative guidance, anatomy recognition, perfusion assessment, surgical safety

1. The Evolution of Computer Vision in Surgery

Computer vision is transitioning from passive image interpretation to active intraoperative assistance. Core capabilities now include anatomy recognition of vessels, nerves, and tissue planes; instrument tracking; perfusion assessment; depth estimation; and real-time alerts for bleeding, structure proximity, and deviation from plan. In plastic surgery these models support perforator identification, free flap pedicle tracking, nerve preservation, and perfusion evaluation during microvascular reconstruction.

2. Key Intraoperative Applications

Anatomy Recognition

Models trained on surgical video can identify arteries and veins, nerves, fat versus muscle versus fascia, and anomalous anatomy, providing an additional layer of perception that helps reduce errors.

Real-Time Perfusion and Tissue Assessment

Integrated with near-infrared, hyperspectral, or standard video, computer vision helps identify ischemia, predict flap viability, guide debridement, and monitor microvascular compromise, benefiting free flap harvest, inset, and postoperative monitoring.

Instrument Recognition and Workflow Guidance

AI can detect when instruments enter the field, when procedural steps begin or end, when checklists need activation, and when documentation milestones occur, supporting safety protocols and automated operative notes.

Hazard Prediction and Coaching

In real time, models may identify bleeding sources, thermal injury risk, proximity to critical structures, and deviations from the planned approach. Computer vision can also quantify motion efficiency, instrument path length, and tissue handling precision for objective skill assessment.

3. Implementation Requirements

- High-quality surgical video data: annotated datasets, multi-angle footage, standardized labeling.
- Low-latency systems: high frame-rate processing and stable edge or hybrid deployment.
- Surgeon control and override: AI remains assistive, never directive.
- OR integration and ergonomics: compatibility with towers, robotic systems, microscopes, and AR.
- Regulatory and safety standards: rigorous validation, failure-mode audits, and prospective trials.

4. Strengths, Limitations, and Safety

Strengths include enhanced anatomical awareness, reduced complication rates, better perfusion prediction, automated documentation, and improved resident training. Limitations include the need for large annotated datasets, variable performance across specialties, degradation from blood, smoke, or lens fog, and the expense of OR integration. Major safety risks include false positives and negatives, overreliance on alerts, incorrect anatomy identification, and system lag during critical moments. Surgeons must treat computer vision as decision support, not a replacement for judgment.

5. What Comes Next

- Multimodal models combining video, vitals, and imaging.
- Autonomous camera control and real-time AR overlays.
- Universal anatomy-recognition models trained across specialties.
- Integration with LLM agents for intraoperative documentation.

Key Takeaways

- Computer vision is becoming a foundational technology inside the OR.
- It enhances safety, precision, and efficiency by augmenting surgeons, not replacing them.
- Plastic surgery offers high-value use cases in free flaps and perforator mapping.
- Implementation requires robust data, validation, and surgeon oversight.