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REVIEW

Predictive Risk Stratification: Using Artificial Intelligence to Anticipate Surgical Complications

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Abstract. Despite advances in technique, many surgical complications are still recognized only after they occur. Predictive risk stratification, using AI models to estimate individual patient risk before surgery, represents a fundamental shift toward proactive, personalized care. By combining clinical history, imaging, laboratory data, social determinants, and procedural variables, AI can generate individualized risk profiles that guide preoperative optimization, procedure selection, and resource planning.

Keywords: risk stratification, predictive modeling, preoperative optimization, shared decision-making, surgical outcomes

1. Why Predictive Risk Stratification Matters

Surgical risk assessment has traditionally relied on surgeon intuition, static scoring systems, and broad population averages. AI enables a more individualized approach by integrating dozens to hundreds of variables simultaneously, updating estimates dynamically, identifying non-obvious risk interactions, and supporting shared decision-making. Models are used to estimate infection risk, wound healing complications, readmission likelihood, thromboembolic events, and the need for revision surgery. In plastic surgery, where procedures may be elective but complications carry significant aesthetic and functional consequences, this is particularly valuable.

2. Data Inputs Powering Predictive Models

- Patient-level variables: age, BMI, smoking status, diabetes, nutrition, medications, surgical history.
- Procedure-specific variables: operative time, complexity, number of sites, implants or grafts.
- Imaging and visual data: preoperative photos, radiographic findings, tissue-quality indicators.
- Laboratory and physiologic data: hemoglobin, albumin, inflammatory markers, renal and hepatic function.
- Social and behavioral factors: access to care, adherence likelihood, distance from center, support systems.

AI models integrate these inputs to generate individualized risk profiles rather than generic probability estimates.

3. Clinical Applications Across Specialties

- General surgery: anastomotic leak risk, high-risk laparotomy identification, length-of-stay anticipation.

- Orthopedics: infection and revision risk after joint replacement, delayed-mobilization prediction.
- Plastic and reconstructive surgery: flap failure, wound healing, capsular contracture, and revision risk.
- Cardiothoracic, vascular, and neurosurgery: major-morbidity stratification and ICU-utilization prediction.

4. How Surgeons Use Predictive Models

Predictive models guide preoperative optimization (smoking cessation, nutritional optimization, glycemic control, or staged procedures), procedure selection and timing, patient counseling grounded in personalized data, and resource planning for ICU needs, length of stay, and post-acute care.

5. Strengths, Limitations, and Ethics

Strengths include personalized risk assessment, earlier identification of high-risk patients, support for shared decision-making, and improved preoperative planning. Limitations include dependence on data quality, variable performance by population, risk of overconfidence in numerical outputs, and poor cross-institution generalization. Ethical risks include bias against underrepresented populations, inappropriate exclusion from care, and over-reliance on algorithmic recommendations. Surgeons must use predictive tools as decision aids, not gatekeepers.

6. Best Practices for Responsible Use

- Validate models locally before deployment and monitor performance over time.
- Include clinicians in model design and oversight.
- Audit for bias and unintended consequences.
- Clearly communicate uncertainty to patients.

Key Takeaways

- Predictive risk stratification shifts surgery from reactive to proactive care.
- AI integrates clinical, procedural, and social factors into individualized risk profiles.
- Plastic surgery provides high-impact use cases due to elective decisions and outcome sensitivity.
- Predictive models must be validated, transparent, and continuously updated.