Outcome of Cataract Surgery: Integrating Surgical Experience, Demographic Variables, and Predictive Modeling

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Background: Cataract surgery is the most common procedure in ophthalmology. Outcomes vary according to patient risk factors, demographic characteristics, and the surgeon's experience—particularly in training settings. Understanding these factors is essential for optimizing case allocation policies and ensuring patient safety during resident training.

Objective: To examine the impact of preoperative risk factors, demographic variables, and surgical experience on cataract surgery outcomes, and to develop predictive tools enabling personalized surgical planning and evidence-based health policy.

Methods: The study analyzed retrospective data from 691 cataract surgeries performed by residents at Hadassah Medical Center between 2018–2022. Variables included preoperative risk scores, intraoperative complications, corrected distance visual acuity (CDVA) before and after surgery, age, sex, operated eye, and surgery timing. A subgroup of 557 patients was further analyzed using logistic regression and a Balanced Random Forest machine learning model (AUC=0.79), with SHAP analysis to identify predictors of non-clinically significant improvement in visual acuity (CDVA <0.1 LogMAR).

Results: With increased experience, the proportion of complex cases operated on by residents rose from 54% to 75–82% (p<0.001), while complication rates declined from 17% to 6%.
Patients with risk factors had lower postoperative visual acuity (0.27 vs. 0.16, p<0.001) and lower improvement rates (57% vs. 63%, p=0.016).
Thresholds for optimal visual acuity outcomes were identified for each age and sex: improvement in visual acuity decreased significantly above age 65 in women and 75 in men.
Among 557 patients, 23% experienced improvement that was not clinically significant. Predictors included older age, having only one functional eye, and longer axial length. Conversely, poorer preoperative visual acuity and surgery on the right eye were protective against non-significant improvement. The predictive model identified preoperative visual acuity, age, resident experience, surgery timing, and operated eye as the most influential factors.
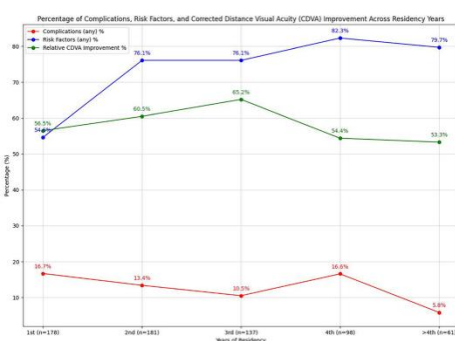
Diminishing Complications with Resident Experience: A decreasing trend noted in intraoperative complications as residents gained experience, despite operating on a greater proportion of high-risk patients.
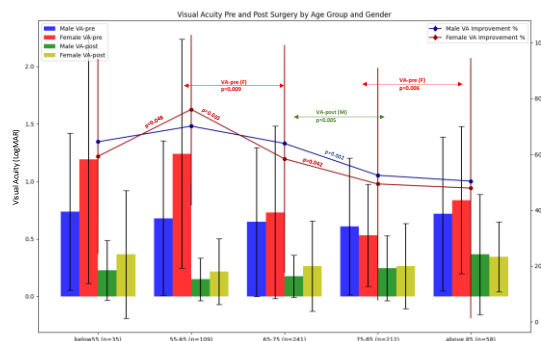
Gender-specific age thresholds for decline in BCVA gains:
Women: After age 65
Men: After age 75
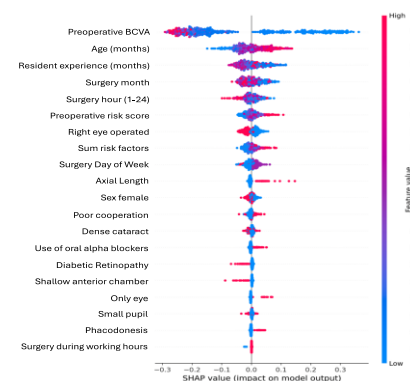
SHAP summary plot illustrating the impact of features predicting NCSI-BCVA. Features are ordered by their impact, with positive SHAP values indicating a higher likelihood of NCSI-BCVA. The color represents the feature value, demonstrating how higher or lower values influence the prediction.

Conclusions and recommendations: Utilizing structured risk models and matching cases to resident experience enhances patient safety and supports gradual resident training. Age- and sex-related differences should be considered in surgical scheduling. Machine learning–based predictive tools can improve patient triage and support more effective cataract surgery policy.

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Disclosure: None