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"A Machine Learning Model to Predict Length of Hospitalization Following Head and Neck Microvascular Free Tissue Transfer"

BACKGROUND: Microvascular free tissue transfer is the standard method of reconstruction for large or complex head and neck defects, with success rates reported between 95% and 99%[1-3]. Postoperative length of stay typically ranges from 8 to 26 days and is influenced by comorbidities, complications, and socioeconomic challenges[1-3]. Prolonged operative time, flap takeback, wound breakdown, surgical site infection, and pneumonia have all been associated with extended hospitalization[1-3]. Analyses of these predictors have relied primarily on regression-based methods, with limited development of robust predictive models. Machine learning (ML) is a type of artificial intelligence that uses patterns and associations between variables to predict outcomes. The present study aims to expand on the currently limited ML techniques in the context of head and neck surgery, including the first AI model to include a causal analysis for prediction of head and neck microvascular surgery length of hospitalization.

METHODS: A retrospective review was conducted for patients undergoing free flap reconstruction of head and neck defects between 2022 and 2025 at a single academic institution. Collected variables included demographics, comorbidities, defect and flap type, pathology, preoperative labs, intraoperative details, and postoperative course. After de-identification and preprocessing, mutual information (MI) analysis identified features for ML analysis. Four regression models were trained to predict log-transformed length of stay. Causal inference was performed using a Peter Clark algorithm, supplemented by physician expertise and literature-derived relationships to construct a final causal graph.

RESULTS: MI analysis consistently identified Charlson Comorbidity Index (mean MI: 0.147 $\pm$ 0.054, CV: 0.366), preoperative albumin (0.090 $\pm$ 0.039, CV: 0.431), and hypertension (0.087 $\pm$ 0.050, CV: 0.574) as important predictors of hospitalization length. Of the four regression models assessed, the Random Forest Regressor demonstrated the best test set performance. The causal ML analysis revealed peripheral vascular disease as a significant direct predictor of prolonged length of stay (β = 0.237, p = 0.01). Additional variables, including albumin, age, congestive heart failure, and Charlson Comorbidity Index, demonstrated weaker or nonsignificant direct effects within the model. These findings suggest that certain comorbid conditions exert a stronger causal impact than global comorbidity burden alone.

CONCLUSIONS: This study demonstrates that causal ML can enhance prediction of length of stay in patients undergoing head and neck free flap reconstruction. By identifying specific preoperative risk factors with direct causal influence, such models provide valuable information for surgical teams and allow more individualized patient counseling. Incorporating causal ML into perioperative planning may ultimately improve risk assessment, guide resource allocation, and optimize recovery beyond the capabilities of traditional statistical approaches.

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