

Postoperative Complications in Older Adults After Local Surgical Procedures; Risk Factor Analysis and Comparison of Machine Learning Methods

Lokal Cerrahi İşlemler Sonrası Yaşlılarda Ameliyat Sonrası Komplikasyonlar; Risk Faktörü Analizi ve Makine Öğrenme Yöntemlerinin Karşılaştırılması

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Abstract

Older adults frequently undergo excision of cutaneous lesions under local anesthesia and may be at increased risk of postoperative complications due to comorbid conditions and concomitant medications. This study aimed to identify predictors of postoperative complications in patients aged 65 years and older and to compare the predictive performance of logistic regression with machine-learning models. This retrospective study included 314 patients who underwent cutaneous lesion excision under local anesthesia. Demographic, clinical, and perioperative variables were collected and assessed using multivariable logistic regression. Decision tree, random forest, and gradient boosting models were developed using an 80/20 training-testing split. Missing data were imputed, and class imbalance was addressed using resampling techniques. Model performance was evaluated using discrimination, calibration, and decision curve analysis. Postoperative complications occurred in 119 patients (37.9%). Patients with complications were older, had lower body mass index, and more frequently had diabetes, coronary artery disease, and antithrombotic therapy. Logistic regression identified low body mass index, diabetes, and coronary artery disease as independent predictors but demonstrated limited discriminatory ability. Among machine-learning models, the random forest achieved the best performance, with superior discrimination and calibration. Body mass index, perioperative blood pressure, age, and procedure duration were the most influential predictors. Postoperative complications are common among older adult patients undergoing cutaneous surgery under local anesthesia. Low body mass index, cardiometabolic comorbidities, perioperative hemodynamic factors, and operative duration are key determinants of risk. Machine-learning approaches, particularly random forest models, may improve perioperative risk stratification in this population.

Keywords: Cutaneous surgery, Elderly patients, Logistic regression, Machine learning, Postoperative complications

Özet

Yaşlı bireylerde lokal anestezi altında yapılan kutanöz lezyon eksizyonları sık uygulanmakta olup, eşlik eden komorbiditeler ve birlikte kullanılan ilaçlar nedeniyle postoperatif komplikasyon riski artmış olabilir. Bu çalışmanın amacı, 65 yaş ve üzeri hastalarda postoperatif komplikasyonların öngördürücülerini belirlemek ve lojistik regresyon ile makine öğrenmesi modellerinin öngörü performanslarını karşılaştırmaktır. Bu retrospektif çalışmaya, lokal anestezi altında kutanöz lezyon eksizyonu yapılan 314 hasta dahil edildi. Demografik, klinik ve perioperatif değişkenler toplanarak çok değişkenli lojistik regresyon analizi ile değerlendirildi. %80/%20 eğitim-test bölünmesi kullanılarak karar ağacı, random forest ve gradient boosting modelleri geliştirildi. Eksik veriler imputasyon yöntemleriyle tamamlandı ve sınıf dengesizliği yeniden örnekleme teknikleri ile düzeltildi. Model performansı ayırt edicilik, kalibrasyon ve karar eğrisi analizi kullanılarak değerlendirildi. Postoperatif komplikasyonlar 119 hastada (%37.9) gözlemlendi. Komplikasyon gelişen hastalar daha ileri yaşta, daha düşük vücut kitle indeksine (VKİ) sahipti ve diyabet, koroner arter hastalığı ile antitrombotik tedavi öyküsü daha sıktı. Lojistik regresyon analizinde düşük VKİ, diyabet ve koroner arter hastalığı bağımsız öngördürücüler olarak saptandı; ancak modelin ayırt edici gücü sınırlıydı. Makine öğrenmesi modelleri arasında random forest en iyi performansı göstererek daha üstün ayırt edicilik ve kalibrasyon sağladı. VKİ, perioperatif kan basıncı, yaş ve işlem süresi en etkili öngördürücüler olarak belirlendi. Lokal anestezi altında kutanöz cerrahi uygulanan yaşlı hastalarda postoperatif komplikasyonlar sık görülmektedir. Düşük VKİ, kardiyometabolik komorbiditeler, perioperatif hemodinamik faktörler ve işlem süresi komplikasyon riskinin temel belirleyicileridir. Özellikle random forest modelleri olmak üzere makine öğrenmesi yaklaşımları, bu hasta grubunda perioperatif risk sınıflandırmasını iyileştirebilir.

Anahtar Kelimeler: Kutanöz cerrahi, Yaşlı hastalar, Lojistik regresyon, Makine öğrenmesi, Postoperatif komplikasyonlar

Introduction

Minor surgical procedures performed under local anesthesia are increasingly common in elderly patients (1). Although these interventions are generally considered low risk, older individuals represent a vulnerable population characterized by frailty, impaired wound healing, and a high burden of comorbidities. Consequently, postoperative complications may occur more frequently in elderly patients, even after seemingly uncomplicated procedures (2).

Postoperative bleeding, hematoma formation, wound dehiscence, and delayed healing are among the most commonly reported complications following minor cutaneous interventions (3). Cardiovascular comorbidities, including coronary artery atherosclerosis, atrial fibrillation, and peripheral arterial disease, have been known to be related with an increased risk of adverse postoperative outcomes (4, 5).

Accurate preprocedural risk stratification in this population remains challenging in routine practice. Traditional statistical approaches often fail to capture the complex interactions between age, comorbidities, medication use, and perioperative physiological parameters. In this context, machine learning-based methods offer an opportunity to integrate multiple clinical variables and improve individualized risk prediction (6).

The objective of this study was to identify predictors of postoperative complications in patients aged 65 years and older undergoing cutaneous lesion excision under local anesthesia, using both conventional statistical methods and machine learning-based models. By focusing on routinely available clinical and perioperative variables, this study seeks to support general clinical decision-making and improve preprocedural risk assessment in elderly patients encountered in everyday medical practice.

Material and Method

Patient Selection

The present retrospective cohort study included patients aged ≥ 65 years who underwent cutaneous lesion excision under local anesthesia in Plastic, Reconstructive and Aesthetic Surgery clinic of Balıkesir University Hospital between 1 January 2025 and 30 June 2025. Patients were selected with consecutive sampling method. Demographic, clinical, histopathological, and perioperative data were collected, including age, sex, body mass index (BMI), comorbidities, cardiovascular risk

factors, medication use, and perioperative blood pressure measurements. Patients with missing intraoperative data, incomplete outcome information, or who declined participation were excluded. The primary endpoint was the occurrence of postoperative complications.

Statistical Analysis

The dataset was randomly divided into a training cohort (80%) and a testing cohort (20%). Missing values were imputed, and class imbalance was addressed using the Synthetic Minority Over-sampling Technique combined with Tomek Links (SMOTE–Tomek) resampling technique. Model performance was evaluated using discrimination, calibration, and clinical utility metrics, including the area under the receiver operating characteristic curve (ROC AUC) and decision curve analysis. Predictor importance was assessed using the Random Forest model.

Comparative analyses were performed between patients with and without postoperative complications to identify potential baseline characteristics associated with adverse outcomes. Data distribution was examined prior to analysis. The Student's t-test was applied to normally distributed continuous variables, while the Mann–Whitney U test was used for non-normal and ordinal data. Categorical variables were analyzed using the chi-square or Fisher's exact test, depending on cell counts. A p value below 0.05 indicated statistical significance. Multivariable logistic regression was performed to identify independent predictors, with findings presented as odds ratios and 95% confidence intervals. In addition, supervised machine learning models—Decision Tree, Random Forest, and Gradient Boosting—were developed and evaluated concurrently.

The data of the study were statistically analyzed by using IBM SPSS Statistics (version 23.0; IBM Corp., Armonk, NY, USA) and RStudio (version 4.0; R Foundation for Statistical Computing, Vienna, Austria).

This study was conducted in accordance with ethical standards and was approved by the institutional ethics committee (Non-Interventional Research in Health Sciences Ethics Committee of Balıkesir University/07.04.2025/Approval No: 2025/141) and conducted in accordance with the Declaration of Helsinki.

Results

Patients who developed postoperative complications were significantly older and had a lower BMI compared with those without complications. Diabetes mellitus and cardiovascular comorbidities, including coronary artery disease, atrial fibrillation, heart failure, and peripheral artery disease, were more prevalent in the complication group. Use of beta-blockers and anticoagulant therapy, particularly warfarin and

edoxaban, was also more frequent among patients with complications. Although the median CHA₂DS₂-VASc score was identical in both groups, the score distribution was shifted toward higher values in patients with postoperative complications, resulting in a statistically significant difference (Mann–Whitney U test, $p = 0.001$). No significant differences were observed with respect to sex, hypertension, most perioperative blood pressure measurements, operation duration, or malignancy status (Table 1).

Table 1. Baseline characteristics of the study population according to postoperative complication status.

Variable	No complication (n=195)	Complication (n=119)	p-value
Age (years)	74.92 ± 8.00	77.00 ± 8.31	0.027
BMI (kg/m ²)	27.28 ± 4.48	25.82 ± 3.35	0.029
Preoperative SBP (mmHg)	151.53 ± 15.82	149.55 ± 16.44	0.237
Preoperative DBP (mmHg)	75.96 ± 13.56	74.64 ± 13.64	0.757
Intraoperative SBP (mmHg)	150.12 ± 17.17	147.85 ± 18.51	0.394
Intraoperative DBP (mmHg)	74.67 ± 12.64	72.85 ± 11.95	0.396
Mean SBP (mmHg)	148.37 ± 15.75	147.58 ± 16.91	0.639
Mean DBP (mmHg)	74.40 ± 11.85	73.46 ± 11.56	0.515
Local anesthetic dose (mg)	76.82 ± 52.88	78.49 ± 47.60	0.316
Type of Local anesthetic			
Prilokain	10 (5.1%)	13 (10.9%)	0.727
Lidokain	109 (94.9%)	182 (89.1%)	
Operation duration (min)	34.87 ± 15.41	36.26 ± 18.65	0.835
Sex (Male)	90 (46.2%)	67 (56.3%)	0.103
Cardiac disease	12 (6.2%)	32 (26.9%)	0.000
Heart failure	6 (3.1%)	14 (11.8%)	0.005
CAD	10 (5.1%)	32 (26.9%)	0.000
Atrial fibrillation	7 (3.6%)	24 (20.2%)	0.000
Beta-blocker use	7 (3.6%)	24 (20.2%)	0.000
Hypertension	127 (65.1%)	69 (58.0%)	0.251
ACEI/ARB use	125 (64.1%)	68 (57.1%)	0.267
Calcium channel blocker use	68 (34.9%)	46 (38.7%)	0.579
Diabetes mellitus	23 (19.3%)	61 (31.3%)	0.029
Oral antidiabetic use	23 (19.3%)	61 (31.3%)	0.029
Insulin use	15 (7.7%)	10 (8.4%)	0.991
History of stroke	3 (1.5%)	3 (2.5%)	0.677
CHA ₂ DS ₂ -VASc score (median (IQR))	3 (2-4)	3 (3-4)	0.001
Any anticoagulant/antiplatelet	100 (51.3%)	78 (65.5%)	0.018
Aspirin use	87 (44.6%)	51 (42.9%)	0.851
Clopidogrel use	6 (3.1%)	2 (1.7%)	0.715
Rivaroxaban use	4 (2.1%)	8 (6.7%)	0.064
Apixaban use	2 (1.0%)	5 (4.2%)	0.109
Edoxaban use	0 (0.0%)	6 (5.0%)	0.003
Warfarin use	1 (0.5%)	5 (4.2%)	0.031
History of coronary angiography	23 (11.8%)	32 (26.9%)	0.001
Peripheral artery disease	5 (2.6%)	11 (9.2%)	0.019
Malignity	100 (51.5%)	50 (42.0%)	0.139

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CAD, coronary artery disease; CHA₂DS₂-VASc, Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes mellitus, prior Stroke/transient ischemic attack/systemic embolism (2 points), Vascular disease, Age 65–74 years, Sex category (female); IQR, interquartile range.

The predictive performance of the four machine learning models was compared. Logistic regression demonstrated the lowest overall discrimination, with an ROC-AUC of 0.597 and a PR-AUC of 0.510. In contrast, the calibrated Random Forest model consistently achieved

superior discrimination and the most favorable calibration profile among all approaches. (Table 2).

Table 2. Performance of predictive models for postoperative complication prediction.

	ROC-AUC	PR- AUC	Brier	Calib Intercept	Calib Slope
Logistic Regression	0.597	0.510	0.264	-0.350	0.230
Decision Tree	0.712	0.598	0.212	-0.418	0.124
Random Forest (cal.)	0.910	0.867	0.125	0.567	0.985
Gradient Boosting (cal.)	0.744	0.638	0.199	-0.168	0.371

In the logistic regression analysis, low BMI, diabetes mellitus, and coronary artery disease

emerged as independent predictors of postoperative complications (Table 3).

Table 3. Logistic regression analysis of predictors for postoperative complications.

Variable	β Coefficient	Odds Ratio (OR)	95% CI for OR	p-value
Age (years)	0.017	1.017	0.971 – 1.065	0.482
Male sex	0.700	2.014	0.815 – 4.974	0.129
BMI	-0.149	0.862	0.791 – 0.939	0.001
Hypertension	-0.722	0.486	0.213 – 1.107	0.086
Diabetes mellitus	1.658	5.237	2.123 – 12.508	0.001
Coronary artery disease (CAD)	2.256	9.544	1.884 – 48.352	0.006
Atrial fibrillation	1.589	4.898	0.359 – 66.818	0.233
Heart failure	-1.816	0.163	0.014 – 1.910	0.148
CHA ₂ DS ₂ -VASc score	0.286	1.331	0.697 – 2.540	0.386
Procedure duration (min)	-0.002	0.998	0.981 – 1.014	0.786
Mean SBP	0.002	1.002	0.982 – 1.022	0.863
Mean DBP	0.006	1.006	0.980 – 1.033	0.643

A decision tree model with a maximum depth of three was constructed to enhance interpretability. BMI constituted the primary splitting variable, followed by coronary artery disease (CAD) and type of local anesthetic in subsequent nodes (Figure 1).

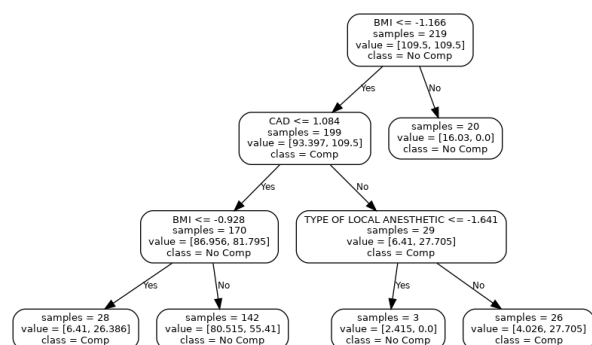


Figure 1. Simplified decision tree for predicting postoperative complications. Each node shows the split criterion and sample proportion; terminal nodes indicate the predicted class (No Complication vs. Complication). The tree was pruned (max depth = 3, min samples per leaf = 3) to enhance interpretability.

ROC curve analyze was preformed to compare the models. The calibrated Random Forest model demonstrated the highest discriminative performance, with an area under the curve of 0.91 in the test set (Figure 2).

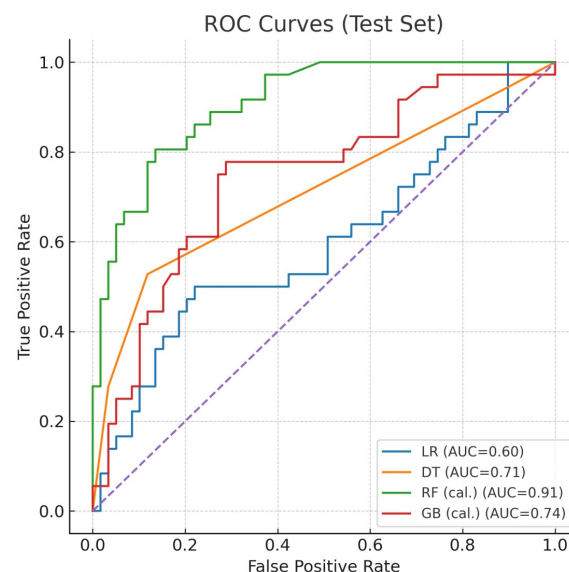


Figure 2. ROC curves of predictive models.

Feature importance analysis of the calibrated Random Forest model identified BMI as the most influential predictor of postoperative complications, followed by preoperative systolic blood pressure and age. Additional contributors included perioperative blood pressure measures, procedure duration, amount of local anesthetic used, the CHA₂DS₂-VASc (Congestive heart failure, Hypertension, Age ≥ 75 years (2 points), Diabetes mellitus, prior Stroke/transient ischemic attack/systemic embolism (2 points), Vascular disease, Age 65–74 years, Sex category) score, and history of coronary artery disease (Figure 3).

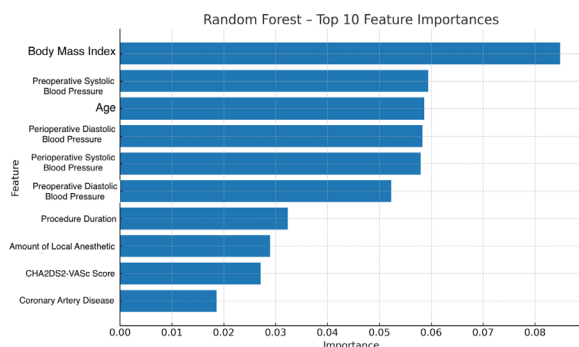


Figure 3. Feature importance plot (Random Forest model).

Discussion

In this study, we evaluated postoperative complications in elderly patients undergoing cutaneous lesion excision under local anesthesia using both conventional statistical methods and machine learning-based approaches. Complications occurred in more than one-third of patients, underscoring that even minor surgical procedures may carry substantial risk in older individuals and highlighting the importance of careful preprocedural risk assessment in routine clinical practice (7).

Baseline comparisons showed that complications clustered predominantly in patients with features consistent with geriatric vulnerability (7). Patients with complications were older and had a lower BMI, suggesting reduced physiological reserve and potential frailty. Diabetes mellitus and cardiovascular comorbidities, particularly coronary artery disease, atrial fibrillation, and heart failure, were also more prevalent, emphasizing the role of global cardiovascular burden in determining perioperative risk (8). In contrast, malignancy status was not associated with an increased complication rate, indicating that patient-related factors may be more influential than lesion characteristics in this setting.

Although no significant differences in perioperative blood pressure values were observed using conventional univariable analyses, perioperative systolic and diastolic blood pressure measures emerged as important predictors in the Random Forest model (9, 10). This finding likely reflects the ability of machine learning methods to capture nonlinear relationships and interaction effects not detectable through mean-based comparisons. The observed U-shaped association between systolic blood pressure and complication risk is biologically plausible, as both hypotension and hypertension may contribute to adverse

outcomes through impaired tissue perfusion and increased bleeding tendency (10). Operative duration, while similar on average between groups, may also interact with hemodynamic instability and patient vulnerability, reflecting procedural complexity and cumulative physiological stress (11).

Medication use further contributed to complication risk. The higher prevalence of beta-blockers and anticoagulant therapy, particularly warfarin and edoxaban, among patients with complications likely reflects both greater cardiovascular disease severity and an increased propensity for bleeding-related adverse events, highlighting the importance of perioperative medication management in elderly patients (12, 13).

From a methodological perspective, machine learning-based models provided clear advantages over conventional approaches (13). While logistic regression and a shallow decision tree showed limited to moderate performance, the calibrated Random Forest model achieved superior discrimination and more reliable risk estimation. This advantage likely stems from the ability of ensemble methods to model complex, nonlinear interactions among demographic, clinical, and perioperative variables. Gradient boosting demonstrated intermediate performance, suggesting partial mitigation of these limitations but greater sensitivity to calibration issues in smaller datasets (14, 15).

Although ensemble models such as Random Forest are less transparent than traditional regression-based approaches, several techniques were used to improve their clinical interpretability (16). Variable importance analysis was applied to identify which factors contributed most strongly to risk prediction, while partial dependence plots and simplified decision tree visualizations were used to illustrate how changes in key variables were associated with changes in predicted risk (17). These approaches allow clinicians to better understand the model's behavior and the relative influence of different predictors. Importantly, the identified feature importance should be interpreted as reflecting predictive relevance within the model rather than direct causal relationships, and the findings should therefore be viewed as supportive of clinical decision-making rather than evidence of causality (18).

The findings should be interpreted in light of several limitations, including the single-center retrospective nature of the study, a limited number of participants, and the potential influence of

residual confounders. External validation in independent cohorts is required before widespread clinical implementation. Moreover, while the model identifies patients at increased risk, it does not directly inform which targeted interventions are most effective, warranting future prospective studies. One limitation of this study is that the analytical approach may appear complex for a clinical question focusing on minor local procedures. However, elderly patients often have multiple comorbidities and overlapping risk factors, making it difficult to identify the main contributors to postoperative complications using simple statistical methods alone. Therefore, more detailed analytical approaches were used to better understand these relationships. Nevertheless, the complexity of these methods may limit their ease of interpretation in routine clinical practice.

Conclusion

Postoperative complications are common in elderly patients undergoing cutaneous lesion excision under local anesthesia and are driven primarily by patient-related factors. The calibrated Random Forest model provides clinically meaningful risk estimates that may support individualized preprocedural decision-making in everyday practice. Future studies should focus on external validation and integration of such models into clinical pathways linked to actionable risk thresholds.

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Conflict of interest statement

The authors declare no conflicts of interest related to this study.

Ethics Committee Approval

The study was approved by the local ethics committee (Non-Interventional Research in Health Sciences Ethics Committee of Balıkesir University/07.04.2025/Approval No: 2025/141) and conducted in accordance with the Declaration of Helsinki.

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