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Predictors of Early Postoperative Bleeding Following Primary Bariatric Surgery: A Retrospective Cohort Study

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Abstract

Background: Postoperative bleeding is a significant cause of morbidity and the leading indication for reintervention. While various aspects of this complication have been addressed in previous studies, further research is required to more precisely define the influence of specific risk factors using robust statistical modeling for rare events.

Objective: This study aimed to identify predictors of early postoperative bleeding.

Methods: This retrospective cohort study examined the medical records of 13,970 patients who underwent metabolic and bariatric surgery (MBS) between January 2009 and December 2024. Bleeding is defined as a drop in hemoglobin of more than 2 g/dL during the first 24 hours, and at least one of the following: requirement for reoperation or radiological intervention to control bleeding, or Administration of red blood cell transfusions

The independent variables included sex, age, type of surgery, weight, BMI, operative duration, international normalized ratio (INR), smoking status, hypertension, cardiovascular disease, use of combined oral contraceptives, liver injury, splenic injury, major vessel injury, and gastrointestinal perforation. Descriptive statistics, as well as classical logistic regression and Firth's bias-reduced logistic regression, were used to evaluate predictors of postoperative bleeding.

Results: Postoperative bleeding occurred in 58 patients (0.41%). Patients with bleeding had longer operative durations (83.45 min vs. 64.69 min) and higher rates of risk factors, including smoking (65.5% vs. 12.9%), hypertension (34.5% vs. 18.9%), cardiovascular disease (13.8% vs. 3.6%), and use of combined oral contraceptives (22.4% vs. 2.3%). Multivariate Firth's logistic regression showed that smoking (OR = 13.48), hypertension (OR = 2.32), cardiovascular disease (OR = 3.98), use of combined oral contraceptives (OR = 18.61), RYGB surgery (OR = 1.59), operative duration (OR = 1.59), and intraoperative complications were independently associated with postoperative bleeding.

Conclusion: Our results identify specific patient characteristics and intraoperative factors that significantly predict early postoperative bleeding after MBS. Incorporating these predictors into perioperative risk stratification may improve patient outcomes through tailored preventive and monitoring strategies.

Introduction

The prevalence of obesity has risen drastically in recent decades, with the global average increasing from 6.44% to 16.06% between 1990 and 2022, and it is projected to reach nearly 39% by 2040 (1). Obesity represents a profound global health challenge, increasingly recognized not only for its direct health impacts but also for its complex associations with various chronic diseases (2).

Metabolic bariatric surgery (MBS) remains the most effective long-term intervention for severe obesity and its associated medical problems, leading to improvements in quality of life, socioeconomic status,

and overall survival (3–5). In parallel with the obesity epidemic, the number of MBS procedures performed annually has steadily increased (6). Advances such as laparoscopic techniques, standardized perioperative care protocols, and accreditation programs have improved the safety profile of MBS (7). However, the procedure still carries the risk of serious complications (8). Postoperative bleeding, while relatively uncommon overall, is among the most frequent serious adverse events following surgery. It is a significant cause of morbidity and remains the leading indication for reintervention within 30 days of the initial operation (9, 10). Prompt recognition and management are essential, as bleeding can rapidly lead to hemodynamic instability and even mortality; however, the risk assessment can be more important to prevent this complication (11). Bleeding after MBS most often originates from staple lines, but it may also arise from dissected planes, ligated vessels (e.g., short gastric or gastroepiploic vessels), or the abdominal wall (12). Reported rates of postoperative hemorrhage range from 0.4–4.4% after gastric bypass to 0.4–3.4% after sleeve gastrectomy (13, 14).

Despite extensive research on MBS outcomes, methodological challenges remain in studying early postoperative bleeding. Several recent national registry studies confirm that bleeding rates have declined over time; however, they also highlight substantial variation across centers and procedures (14). Moreover, these studies primarily report incidence and risk factors using conventional logistic regression models. Because postoperative bleeding is rare, traditional logistic regression is prone to bias and instability due to sparse data and separation issues (15). To address this gap, bias-reduced methods such as Firth's penalized logistic regression provide more reliable parameter estimates and preserve model validity when events are infrequent (15).

study aimed to identify predictors of early postoperative bleeding after primary bariatric surgery using Firth's bias-reduced logistic regression, thereby enabling clinicians to develop targeted perioperative strategies to reduce risk, enhance patient safety, and optimize surgical outcomes.

Methods

Study Design and Participants

This retrospective cohort study examined the medical records of 13,970 patients who underwent primary metabolic and bariatric surgery (MBS) between January 2009 and December 2024. All data were obtained from the Iran National Obesity Surgery Database (INOSD) (16). Eligible patients were adults aged > 18 years with a body mass index (BMI) of 35–50 kg/m² who underwent laparoscopic sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), one-anastomosis gastric bypass (OAGB), or other primary bariatric surgical procedures. Patients receiving anticoagulant therapy were excluded.

Ethical Considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Ethics Committee of Iran University of Medical

Sciences (Approval No. IR.IUMS.REC.1404.447). As this was a retrospective study based on an existing database and all data were anonymized before analysis, the requirement for informed consent was waived by the Ethics Committee. All patient data were anonymized to ensure privacy and confidentiality.

Outcome Definition and Study Variables

The primary outcome was early postoperative bleeding, defined as a decrease in hemoglobin concentration of > 2 g/dL during the first 24 hours after surgery, accompanied by at least one of the following: (1) reoperation or radiological intervention for bleeding control, or (2) administration of red blood cell transfusion.

The independent variables included sex, age, type of surgery, body weight, BMI, operative duration, international normalized ratio (INR), smoking status, hypertension (HTN), cardiovascular disease (CVD), use of combined oral contraceptives, liver injury, splenic injury, major vascular injury, and gastrointestinal perforation.

Statistical Analysis

Univariate and multivariable logistic regression models were used to evaluate potential predictors of early postoperative bleeding. In the univariate analysis, each covariate was assessed independently to estimate its crude association with the outcome. Variables with a p-value < 0.10 in the univariate analysis, together with age and sex based on their clinical relevance, were included in the multivariable model. Multicollinearity among independent variables was assessed using the variance inflation factor (VIF) before multivariable analysis.

Although the overall sample size was large (n = 13,970), postoperative bleeding was a rare event, occurring in only 58 patients. Therefore, to address potential small-sample bias and separation associated with rare events, Firth's bias-reduced logistic regression was additionally performed using the logistf package in R. For both conventional and Firth logistic regression models, beta coefficients, standard errors (SEs), odds ratios (ORs), 95% confidence intervals (CIs), and p-values were reported.

Missing data were identified for smoking status (0.27%), operative duration (15.35%), and INR (6.91%). Missing values were handled using multiple imputation by chained equations (MICE) in R before statistical analysis.

The discriminative performance of the conventional and Firth logistic regression models was assessed using the area under the receiver operating characteristic curve (AUC) with 95% CIs. The optimal predicted-probability cutoff for each model was determined using the maximum Youden index (sensitivity + specificity − 1). Sensitivity and specificity at the optimal cutoff were reported, and observed versus predicted classifications were presented using confusion matrices.

All statistical analyses were performed using R software, version 4.5.0. A two-sided p-value < 0.05 was considered statistically significant.

Results

A total of 13,970 patients were included, of whom 58 (0.41%) experienced postoperative bleeding. The mean age was approximately 39 years in both groups. Regarding the type of surgery, 52% of patients underwent one-anastomosis gastric bypass (OAGB), 24% underwent sleeve gastrectomy (SG), 21.8% underwent Roux-en-Y gastric bypass (RYGB), and 2.2% underwent other bariatric procedures.

Patients with bleeding had longer operative duration (83.45 min vs. 64.69 min), and higher rates of risk factors including smoking (65.5% vs. 12.9%), hypertension (34.5% vs. 18.9%), cardiovascular disease (13.8% vs. 3.6%), use of combined oral contraceptives (22.4% vs 2.3%), and intraoperative complications such as liver injury, splenic injury, major vessel injury, and gastrointestinal perforation (GIP) (see Table 1).

Table 1
Basic demographic characteristics and clinical features of all patients

Variable	No Bleeding (n = 13912)	Bleeding (n = 58)	Total (n = 13970)
Age	39.33 ± 10.42	38.95 ± 9.52	39.33 ± 10.42
Duration	64.69 ± 19.35	83.45 ± 32.13	64.77 ± 19.45
Weight	117.36 ± 22.17	117.09 ± 22.94	117.36 ± 22.18
BMI	43.44 ± 6.40	42.33 ± 6.31	43.43 ± 6.40
INR	1.13 ± 2.70	1 ± 0	1.13 ± 2.70
Gender			
Female	10979 (78.9%)	40 (69.0%)	11019 (78.9%)
Male	2933 (21.1%)	18 (31.0%)	2951 (21.1%)
Surgery Type			
SG	3359 (24.1%)	12 (20.7%)	3371 (24.1%)
OAGB	7229 (52.0%)	23 (39.7%)	7252 (51.9%)
RYGB	3025 (21.7)	20 (34.5%)	3045 (21.8%)
Others	299 (2.1%)	3 (5.2%)	302 (2.2%)
Smoking			
No	12118 (87.1%)	20 (34.5%)	12138 (86.9%)
Yes	1794 (12.9%)	38 (65.5%)	1832 (13.1%)
HTN			
No	11277 (81.1%)	38 (65.5%)	11315 (81.0%)
Yes	2635 (18.9%)	20 (34.5%)	2655 (19.0%)
CVD			
No	13405 (96.4%)	50 (86.2%)	13455 (96.3%)
Yes	507 (3.6%)	8 (13.8%)	515 (3.7%)
Combined Oral Contraceptives			
No	13588 (97.7%)	45 (77.6%)	13633 (97.6%)
Yes	324 (2.3%)	13 (22.4%)	337 (2.4%)

Variable	No Bleeding (n = 13912)	Bleeding (n = 58)	Total (n = 13970)
Liver Injury			
No	13906 (100.0%)	55 (94.8%)	13961 (99.9%)
Yes	6 (0.0%)	3 (5.2%)	9 (0.1%)
Splenic Injury			
No	13871 (99.7%)	56 (96.6%)	13927 (99.7%)
Yes	41 (0.3%)	2 (3.4%)	43 (0.3%)
Major Vessel Injury			
No	13908 (100.0%)	55 (94.8%)	13963 (99.9%)
Yes	4 (0.0%)	3 (5.2%)	7 (0.1%)
Gastrointestinal Perforation			
No	13869 (99.7%)	55 (94.8%)	13924 (99.7%)
Yes	43 (0.3%)	3 (5.2%)	46 (0.3%)

In univariate analysis, significant risk factors for postoperative bleeding included smoking (OR: 12.83, 95% CI: 7.54–22.52, $p < 0.001$), hypertension (OR: 2.25, 95% CI: 1.28–3.83, $p = 0.003$), cardiovascular disease (OR: 4.23, 95% CI: 1.85–8.47, $p < 0.001$), and use of combined oral contraceptives (OR: 12.12, 95% CI: 6.22–22.03, $p < 0.001$). Intraoperative complications—including liver injury, splenic injury, and major vessel injury—were associated with high odds ratios and wide confidence intervals. Therefore, these results should be interpreted with caution. RYGB was also significantly associated with postoperative bleeding (OR: 2.08, $p < 0.05$), indicating that the odds of postoperative bleeding were approximately 2.08 times higher in patients undergoing RYGB than in those undergoing OAGB.

Operative duration was scaled in 30-minute increments to facilitate interpretation. Accordingly, an odds ratio of 1.60 indicates that for each additional 30-minute increase in operative time, the odds of postoperative bleeding increased by 60%.

In the next step, multivariate logistic Regression was conducted to adjust for potential confounding factors. No significant multicollinearity was detected among the predictors, as all Variance Inflation Factor (VIF) values were less than 1.21, indicating model stability. Multivariate analysis confirmed smoking (OR: 14.46, 95% CI: 7.89–27.36), hypertension (OR: 2.36, 95% CI: 1.19–4.54), cardiovascular disease (OR: 4.02, 95% CI: 1.48–9.64), use of combined oral contraceptives (OR: 19.32, 95% CI: 8.75–41.35), operative duration (OR per 30 minutes: 1.58, 95% CI: 1.26–1.90), and intraoperative complications as independent risk factors. However, after adjustment, RYGB was no longer significantly

different from OAGB regarding the risk of postoperative bleeding (OR: 1.80, 95% CI: 0.91–3.51). (Table 2).

Table 2
Univariate and Multivariate Classic Logistic Regression Analysis of Factors Associated with Postoperative Bleeding

Model	Covariates	Beta	SE	OR	95% CI for OR		*p*
					Lower	Upper	
Simple	Age	-0.004	0.013	0.996	0.972	1.021	0.779
	Gender (Male)	0.521	0.285	1.684	0.942	2.896	0.067
	Surgery Type						
	SG	0.116	0.357	1.123	0.540	2.217	0.745
	RYGB	0.731	0.306	2.078	1.130	3.790	0.017
	Others	1.148	0.617	3.153	0.745	9.123	0.062
	OAGB	Ref.					
	Smoking	2.552	0.277	12.834	7.540	22.519	< 0.001
	HTN	0.812	0.277	2.252	1.284	3.832	0.003
	CVD	1.442	0.383	4.230	1.846	8.472	< 0.001
	COC	2.494	0.320	12.116	6.222	22.031	< 0.001
	Liver Injury	4.840	0.720	126.418	26.168	492.086	< 0.001
	Splenic Injury	2.492	0.736	12.083	1.940	40.625	< 0.001
	Vessel Injury	5.245	0.776	189.655	36.657	879.671	< 0.001
	GIP	2.867	0.612	17.593	4.179	50.168	< 0.001
	Duration	0.473	0.076	1.605	1.365	1.852	< 0.001
	INR	-7.665	3.622	0.000	0.000	0.062	0.034
Multiple	Intercept	-8.441	4.011				0.035
	Age	0.005	0.016	1.005	0.974	1.037	0.733
	Gender (Male)	0.335	0.353	1.398	0.691	2.783	0.343
	Surgery Type						
	SG	-0.031	0.381	0.969	0.443	2.002	0.935
	RYGB	0.586	0.342	1.798	0.909	3.505	0.086
	Others	0.606	0.813	1.833	0.278	7.321	0.456
	OAGB	Ref.					

Smoking	2.671	0.339	14.458	7.886	27.365	< 0.001
HTN	0.857	0.338	2.357	1.193	4.543	0.012
CVD	1.391	0.473	4.017	1.476	9.643	0.003
COC	2.961	0.393	19.316	8.752	41.353	< 0.001
Liver Injury	5.120	1.043	167.298	18.415	1139.530	< 0.001
Splenic Injury	2.403	0.877	11.059	1.459	51.011	0.006
Vessel Injury	4.422	1.18	83.236	7.938	840.872	< 0.001
GIP**	1.759	0.824	5.808	0.852	24.000	0.033
Duration	0.457	0.103	1.579	1.258	1.903	< 0.001
INR	-8.54	3.861	0.000	0.000	0.022	0.027

*For categorical variables, the reference group was “female” for gender and “No” for all other categorical variables.

** Although the p-value suggests significance, the more robust 95% CI includes 1, so this finding should be interpreted with caution and not considered statistically significant at the 0.05 level.

Multivariate Firth’s logistic regression yielded similar results, with smoking (OR: 13.48, 95% CI: 7.44–25.13), hypertension (OR: 2.32, 95% CI: 1.18–4.43), cardiovascular disease (OR: 3.98, 95% CI: 1.50–9.35), use of combined oral contraceptives (OR: 18.61, 95% CI: 8.58–39.15), operative duration (OR per 30 minutes: 1.59, 95% CI: 1.28–1.89), and intraoperative complications all remaining significant predictors (see Table 3).

Table 3
Univariate and Multivariate Firth's Bias-Reduced Logistic Regression Analysis of Factors Associated with Postoperative Bleeding

Model	Covariates	Beta	SE	OR	95% CI for OR		*p*
					Lower	Upper	
Simple	Age	-0.003	0.013	0.997	0.972	1.021	0.791
	Gender (Male)	0.536	0.281	1.710	0.963	2.923	0.066
	Surgery Type						
	SG	0.135	0.351	1.145	0.558	2.237	0.702
	RYGB	0.734	0.303	2.084	1.141	3.776	0.017
	Others	1.280	0.576	3.595	0.958	9.825	0.057
	OAGB	Ref.					
	Smoking	2.540	0.275	12.683	7.489	22.115	< 0.001
	HTN	0.824	0.274	2.278	1.307	3.856	0.004
	CVD	1.492	0.373	4.446	1.990	8.766	< 0.001
	COC	2.520	0.315	12.425	6.454	22.409	< 0.001
	Liver Injury	4.905	0.676	134.921	31.464	488.622	< 0.001
	Splenic Injury	2.694	0.665	14.79	2.991	45.285	0.003
	Vessel Injury	5.273	0.725	194.914	42.728	819.099	< 0.001
	GIP	3.001	0.572	20.107	5.385	54.187	< 0.001
	Duration	0.479	0.073	1.614	1.384	1.856	< 0.001
	INR	0.022	0.010	1.022	0.956	1.039	0.181
Multiple	Intercept	-16.767	1.236				< 0.001
	Age	0.006	0.015	1.006	0.975	1.038	0.705
	Gender	0.309	0.332	1.362	0.683	2.671	0.375
	Surgery Type						
	SG	-0.055	0.361	0.946	0.439	1.930	0.882
	RYGB	0.574	0.323	1.776	0.911	3.416	0.091
	Others	0.619	0.715	1.857	0.323	6.781	0.441
	OAGB	Ref.					

Smoking	2.601	0.300	13.477	7.437	25.134	< 0.001
HTN	0.841	0.321	2.320	1.185	4.430	0.015
CVD	1.381	0.444	3.977	1.502	9.347	0.007
COC	2.923	0.374	18.606	8.576	39.146	< 0.001
Liver Injury	5.153	0.951	172.969	19.869	1126.882	< 0.001
Splenic Injury	2.411	0.808	11.149	1.713	50.541	0.015
Vessel Injury	4.286	1.046	72.707	8.007	727.009	< 0.001
GIP	1.827	0.729	6.218	1.067	23.285	0.043
Duration	0.463	0.093	1.589	1.280	1.895	< 0.001
INR	0.029	0.010	1.030	0.943	1.048	0.139

*For categorical variables, the reference group was “female” for gender and “No” for all other categorical variables.

The classic logistic regression model achieved an AUC of 0.911 (95% CI: 0.872–0.949), and the Firth model an AUC of 0.905 (95% CI: 0.865–0.946), indicating excellent discriminative ability for both models (see Table 4). Sensitivity and specificity at the Youden index optimal cutoff for the classic model were 0.879 and 0.820, respectively; for the Firth model, 0.879 and 0.810, respectively. Figure 1 illustrates the ROC curves comparing the classic and Firth logistic regression models for predicting postoperative bleeding. As shown, both classic and Firth logistic models demonstrated nearly equal discriminative performance.

Table 4
Discriminative Performance of Classic and Firth Logistic Regression Models

Model	**AUC**	**95% CI for AUC**		**Best Cutoff**	**Sensitivity**	**Specificity**
		Lower	**Upper**			
Classic Logistic	0.911	0.872	0.949	0.003	0.879	0.820
Firth Logistic	0.905	0.865	0.946	0.004	0.879	0.810

At the best cutoff point determined by the Youden index for each model. The classic logistic regression classified 11,408 true negatives, 7 false negatives, 2,504 false positives, and 51 true positives. In comparison, the Firth logistic regression classified 11,274 true negatives, 7 false negatives, 2,638 false positives, and 51 true positives (see Table 5).

Table 5
Observed and Predicted Classification Results at the Youden Index-Based Best Cutoff for Classic and Firth Logistic Models

Model	Predicted	Observed	
		No	Yes
Classic Logistic	No	11408	7
	Yes	2504	51
Firth Logistic	No	11274	7
	Yes	2638	51

Discussion

In this large retrospective cohort of 13,970 patients undergoing MBS, the overall incidence of postoperative bleeding within the first 24 hours was 0.41%. However, several independent risk factors were identified with high statistical significance. Reported rates of postoperative hemorrhage range from 0.4% to 4.4% after gastric bypass and from 0.4% to 3.4% after sleeve gastrectomy (13, 14). We found an incidence of bleeding lower than that in recent studies; these results may be due to the different definition of postoperative bleeding in various studies, improvements in surgical techniques, and the advancement of surgical instruments (staplers and energy devices) (17, 18).

Multivariate analysis on our data demonstrated that smoking, hypertension, cardiovascular disease, use of combined oral contraceptives (COCs), prolonged operative duration, and intraoperative complications were significant predictors of early postoperative bleeding. These findings were consistent across both classical and Firth's bias-reduced logistic regression models, supporting the robustness of the results despite the rarity of the event. Previous studies have identified several factors significantly associated with an increased risk of postoperative bleeding, including male sex, hypertension, prolonged hospital stay, revisional surgery, higher rates of major complications, and preoperative administration of enoxaparin (19, 20). Other authors have reported type 2 diabetes, renal insufficiency, and preoperative therapeutic anticoagulation as additional factors associated with postoperative bleeding (21). Interestingly, demographic factors such as age and sex were not significantly associated with bleeding risk, suggesting that modifiable perioperative factors and patient comorbidities may be more critical determinants. In the unadjusted analysis, RYGB was associated with a higher likelihood of postoperative bleeding; however, this association was no longer statistically significant after adjustment, suggesting that the observed difference may be influenced by confounding factors rather than the surgical technique itself.

Smoking was associated with an increased risk of bleeding (OR ≈ 13–14), aligning with prior literature reporting impaired wound healing, microvascular dysfunction, and platelet activation as mechanisms that increase bleeding risk in surgical patients. Similarly, the observed association with hypertension and

cardiovascular disease may reflect underlying vascular fragility, anticoagulant or antiplatelet use, and hemodynamic instability. The markedly elevated odds ratio associated with COC use (≈ 18) highlights the potential influence of estrogen-mediated changes in coagulation and vascular permeability, a factor that may be underappreciated in bariatric surgery risk assessment (22).

Prolonged operative duration was also independently predictive of bleeding. Longer operative times may indicate greater technical complexity, increased tissue handling, or intraoperative challenges, each contributing to postoperative hemorrhage risk. The extremely high odds ratios observed for intraoperative injuries—particularly to the liver, spleen, and major vessels—are biologically plausible and emphasize the importance of meticulous dissection, hemostasis, and intraoperative vigilance in preventing early bleeding events (23).

The high discriminative ability of our predictive models (AUC ≈ 0.91) indicates strong potential for clinical application in preoperative counseling, perioperative planning, and targeted postoperative monitoring (18).

From a clinical perspective, these findings suggest that high-risk patients—particularly those with a smoking history, hypertension, cardiovascular disease, or COC use—may benefit from enhanced perioperative hemostatic strategies, reconsideration of modifiable risk factors before surgery, and more intensive postoperative surveillance. Furthermore, given the very high bleeding risk associated with intraoperative injuries, structured surgical training, careful patient selection, and adherence to standardized operative protocols remain essential.

This study’s strengths include its large sample size, robust statistical approach, and use of bias-reduced logistic regression to address rare-event bias. However, the relatively small number of bleeding events compared with the number of covariates may increase the risk of overfitting; consequently, some predictors—especially rare intraoperative complications—showed wide confidence intervals and should be interpreted cautiously as associations rather than causal effects. In addition, the very low incidence of postoperative bleeding (0.41%) may limit the positive predictive value and clinical applicability of the model despite its high discrimination. Other limitations include the retrospective, single-center design, possible reporting bias in recorded intraoperative events, and the lack of data on factors such as stapler type and size, staple-line reinforcement, herbal drug use (e.g., garlic), and other potential confounders. Future prospective studies could validate these findings and explore interventions to mitigate identified risks, particularly in high-risk subgroups.

In conclusion, our results identify specific patient characteristics and intraoperative factors that significantly predict early postoperative bleeding after MBS. Incorporating these predictors into perioperative risk stratification may improve patient outcomes through tailored preventive and monitoring strategies.

Declarations

Competing interests

The author(s) declare no competing interests

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Author Contribution

Sanaulhaq Saqeb: Collecting and Clearing DataAbdolreza Pazouki: Presenting the Main IdeaTofigh Mobaderi: Data AnalysisShahab Shahabi Shahmiri: Text EditingSeyed Nooredin Daryabari: Text EditingDarokhan Malakzoi: Collecting DataFahime Yarigholi: Writing the main text

Data Availability

All data were obtained from the Iran National Obesity Surgery Database (INOSD). Restrictions apply to the availability of these data, which were used under license for the current study and so are not publicly available. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

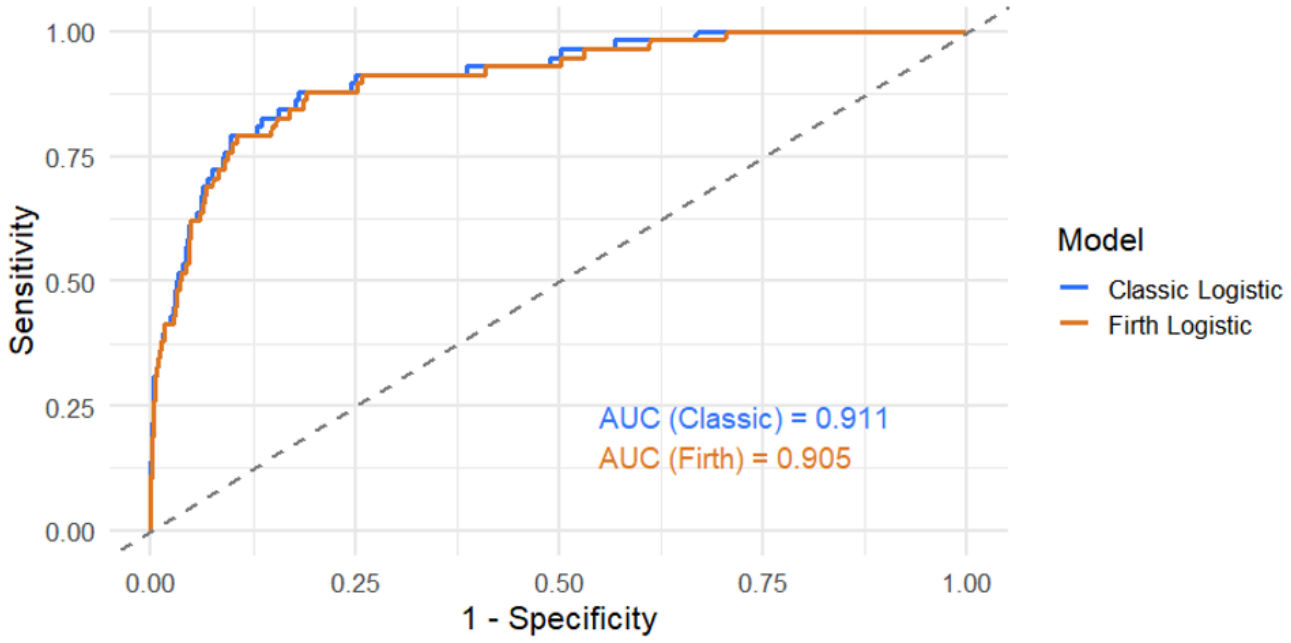


Figure 1

ROC curve comparison of classic and Firth logistic regression models for the prediction of postoperative bleeding