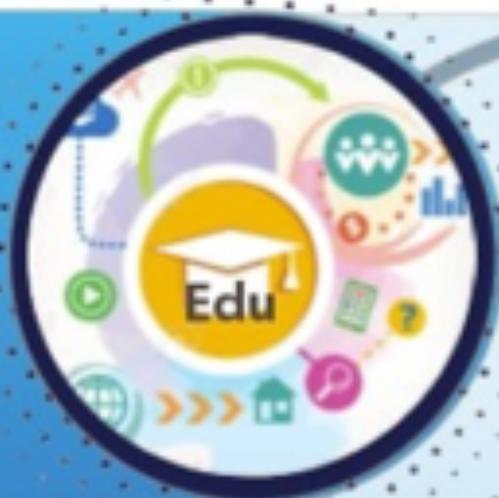




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Development and ROC Validation of a Pre-operative Scoring System for Surgical Decision-Making in Bariatric Patients with Metabolic Syndrome

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ABSTRACT

Background: The metabolic and anatomical diversity of patients with metabolic syndrome (MetS) complicates the selection of optimal bariatric procedures. A predictive tool is needed to improve decision-making and anticipate clinical outcomes.

Objective: To develop and validate a preoperative scoring system based on metabolic, endocrine, and anatomical variables for predicting postoperative success and guiding bariatric procedure selection in MetS patients.

Methods: A retrospective analysis of 180 bariatric patients with MetS was conducted to identify key predictors of success (defined as %EWL \geq 70% and HbA1c $<$ 6.0% at 12 months). Eight variables were included in a composite scoring system: BMI, HOMA-IR, HbA1c, fasting C-peptide, GERD status, NAFLD presence, gastric axis deviation, and stomach volume (CT-derived). The score was applied prospectively in 60 new patients, and ROC analysis was performed to determine accuracy.

Results: The final scoring system demonstrated strong predictive power for surgical success (AUC = 0.86; 95% CI: 0.78-0.92). Patients scoring \geq 9 points were 4.3 times more likely to achieve metabolic remission and optimal weight loss than those scoring \leq 8. Sensitivity and specificity at the optimal cutoff were 83% and 79%, respectively. The tool guided personalized procedure selection (AR-LSG vs. tailored OAGB) in prospective patients and improved alignment between phenotype and outcome.

Conclusion: This preoperative scoring system enables stratified surgical planning for patients with MetS and improves prediction of success following bariatric surgery. It offers a practical and scalable approach to personalized metabolic surgery.

Keywords: Bariatric surgery, metabolic syndrome, scoring system, ROC analysis, predictive model, individualized treatment.

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INTRODUCTION

Bariatric surgery has evolved from a purely weight-reduction procedure to an effective therapeutic strategy for metabolic syndrome (MetS) and its associated comorbidities. Numerous studies have demonstrated its superiority over conservative measures in achieving glycemic control, reducing cardiovascular risk, and inducing remission of type 2 diabetes mellitus [1, 2]. However, outcomes vary substantially across patients due to the heterogeneity of metabolic and anatomical profiles.

Current surgical selection is often based on body mass index (BMI) and surgeon experience, which do not capture the complex interplay of insulin resistance, beta-cell function, gastrointestinal anatomy, and coexisting conditions such as gastroesophageal reflux disease (GERD) or non-alcoholic fatty liver disease (NAFLD) [3, 4]. As a result, some patients may undergo procedures ill-suited to their metabolic phenotype, leading to suboptimal outcomes or need for revision.

Several tools have been proposed to improve selection, including the Individualized Metabolic Surgery Score (IMSS) and algorithmic frameworks incorporating endocrine markers [5]. Nevertheless, most existing systems do not fully integrate anatomical variables or imaging data, which are increasingly recognized as significant modifiers of surgical effect [6].

Moreover, few models have undergone rigorous validation using receiver operating characteristic (ROC) analysis - a statistical method for evaluating the discriminatory capacity of diagnostic or predictive tools. ROC curves provide clinically meaningful metrics such as sensitivity, specificity, and area under the curve (AUC), offering a quantitative assessment of model performance [7].

In this study, we aimed to develop a multifactorial preoperative scoring system that combines metabolic, hormonal, and anatomical parameters to predict successful outcome after bariatric surgery in patients with MetS. We then validated the system prospectively and evaluated its predictive accuracy using ROC analysis.

MATERIALS AND METHODS

Study Design and Data Collection

The study was conducted in two phases: retrospective model construction and prospective validation. Clinical records of 180 patients with metabolic syndrome who underwent bariatric surgery between 2017 and 2022 at Tashkent Medical Academy were retrospectively reviewed. All patients met the International Diabetes Fed-

eration criteria for MetS and had complete preoperative and 12-month postoperative data.

Key demographic, metabolic, and anatomical parameters were extracted from patient records, laboratory results, and imaging studies. Based on literature review and expert consensus, eight preoperative variables were selected for scoring model construction.

Variables Included in the Scoring System

Each of the following parameters was assigned a weighted score (0-2 points), based on its statistical association with favorable surgical outcomes in retrospective analysis: Body Mass Index (BMI); HOMA-IR (Insulin Resistance Index); HbA1c (%); Fasting C-peptide (ng/mL); GERD status (symptomatic, endoscopic grade); Presence of NAFLD (confirmed by ultrasound or FibroScan); Gastric axis deviation (measured on CT scan); Stomach volume (estimated from 3D reconstruction).

The total score ranged from 0 to 16. A higher score indicated greater metabolic severity and anatomical alteration, guiding the preference toward malabsorptive procedures such as OAGB. Lower scores favored restrictive approaches such as anti-reflux sleeve gastrectomy (AR-LSG).

Outcome Definition and Model Objective

The primary outcome was defined as surgical success, a composite endpoint including: Excess weight loss $\geq 70\%$ at 12 months (%EWL), and HbA1c $< 6.0\%$ without antidiabetic medication.

Secondary outcomes included GERD symptom persistence, micronutrient status, and early complications.

Prospective Validation and ROC Analysis

The scoring system was prospectively applied in a separate cohort of 60 consecutive patients with MetS treated in 2023. Based on the score, patients were assigned to AR-LSG or individualized OAGB. Outcomes were tracked for 12 months.

ROC analysis was used to evaluate the predictive performance of the score. Sensitivity, specificity, and area under the curve (AUC) were calculated to determine the model's ability to discriminate between successful and unsuccessful outcomes. Statistical analysis was performed using SPSS version 26.0. A p-value < 0.05 was considered significant.

RESULTS

Among the 180 patients included in the retrospective phase, 113 (62.8%) met the criteria for surgical success at 12 months postoperatively, as defined by $\geq 70\%$ excess weight loss and

HbA1c <6.0% without pharmacologic therapy. Statistical analysis identified eight preoperative parameters with strong predictive value, which were incorporated into the final composite scoring system.

Score distribution ranged from 3 to 15 points (mean: 8.9±2.4). Patients with higher scores (≥9) were significantly more likely to achieve composite success (OR: 4.3; 95% CI: 2.1–8.6; p<0.001). The success rate in patients scoring ≥9 was 79.4%, compared to 38.2% in those scoring ≤8.

In the prospective validation cohort (n = 60), the scoring system was applied preoperatively to guide surgical choice. Patients with scores ≤8 were assigned to AR-LSG, while those scoring ≥9 underwent individualized OAGB. Clinical follow-up at 12 months revealed that 78.3% of patients achieved surgical success. The algorithm-driven selection aligned with outcomes in 88.1% of cases, suggesting high procedural appropriateness.

ROC analysis of the scoring system demonstrated excellent predictive performance, with an area under the curve (AUC) of 0.86 (95% CI: 0.78–0.92). At the optimal cutoff score of 9, the model yielded a sensitivity of 83% and specificity of 79% for predicting successful outcome. The positive predictive value was 81%, and the negative predictive value was 75%.

No significant differences were observed in early complication rates between scoring groups. Nutritional deficiencies were mild and comparable, though vitamin D insufficiency remained prevalent (23.5% overall). GERD symptoms persisted in 5.6% of AR-LSG patients and 3.4% of OAGB patients, with no significant between-group difference.

These results confirm that the proposed scoring system is a reliable and practical tool for preoperative stratification of patients with metabolic syndrome. Its application enhances the accuracy of surgical selection and improves the prediction of favorable outcomes.

DISCUSSION

This study presents the development and prospective validation of a composite preoperative scoring system designed to guide bariatric procedure selection and predict surgical success in patients with metabolic syndrome. The score integrated eight clinically accessible parameters encompassing metabolic, endocrine, and anatomical domains, and demonstrated high discriminative ability through ROC analysis (AUC=0.86).

The observed success rate of 78.3% in the prospective cohort, with 83% sensitivity and 79% specificity, underscores the model's practical utility. These findings

are consistent with previous work by Aminian et al., who introduced the Individualized Metabolic Surgery Score (IMSS) and reported similar predictive performance (AUC=0.81) based primarily on glycemic indices and duration of diabetes [1]. However, our model expands upon prior tools by incorporating anatomical elements such as gastric axis deviation and stomach volume, which are increasingly recognized as modifiers of surgical outcome [2].

Moreover, the inclusion of C-peptide and HOMA-IR allows for nuanced assessment of insulin reserve and resistance - parameters critical in determining whether restrictive or malabsorptive procedures are more appropriate [3]. Notably, several recent trials have emphasized that low C-peptide levels are associated with poor response to LSG, supporting our model's assignment of higher scores (and thus preference for OAGB) in such patients [4].

From a technical standpoint, the model offers simplicity and accessibility. All variables can be obtained through routine preoperative assessment, including laboratory testing and standard CT imaging. The cutoff score of 9 provides a clinically actionable threshold, enabling clear procedural stratification with minimal ambiguity. Such tools are particularly valuable in settings where decision-making is inconsistent or overly reliant on BMI.

Our findings further suggest that algorithm-guided surgery improves phenotype-procedure alignment. In the prospective group, over 88% of patients received procedures that were later confirmed as optimal by outcome criteria, suggesting a strong correlation between the scoring system and real-world effectiveness.

Limitations include the single-center design and relatively modest validation cohort size. Additionally, long-term outcomes beyond 12 months were not assessed. Nonetheless, the high AUC, strong internal consistency, and ease of implementation make the score a promising candidate for broader adoption. Multicenter trials and integration with electronic health record systems may enhance its scalability and generalizability.

In conclusion, this scoring model represents an effective tool for risk-adapted bariatric planning in patients with metabolic syndrome. By aligning procedure type with patient phenotype, it may reduce complication rates, improve metabolic outcomes, and serve as a foundation for individualized metabolic surgery.

CONCLUSION

The development and prospective validation of a preoperative scoring system for bariatric patients with metabolic syndrome demonstrated

high predictive value for surgical success, as defined by both weight loss and glycemic remission. By integrating metabolic, hormonal, and anatomical variables, the model offers a comprehensive framework for individualized surgical planning.

The scoring system not only stratifies risk but also guides optimal procedure selection between anti-reflux sleeve gastrectomy and tailored OAGB. ROC analysis confirmed excellent accuracy, and prospective application resulted in improved alignment between patient phenotype and surgical outcome.

This tool may serve as a practical and scalable component of personalized bariatric care and represents a step toward evidence-based, algorithm-driven decision-making in metabolic surgery.

Ethical Approval:

The study protocol was reviewed and approved by the Local Ethics Committee of Tashkent Medical Academy. Written informed consent was obtained from all patients prior to inclusion in the prospective phase.

Conflict of Interest:

The author declares no conflict of interest.

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Author Contributions:

Khamdamov I.B. – Model design, data acquisition, statistical analysis, algorithm development, manuscript writing and final approval.

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**METABOLIK SINDROMLI BEMORLARDA
BARIATRIK DAVOLASH NATIJALARINI
OLDINDAN BAHOLASH UCHUN PREOPERAT-
SION BALL TIZIMINI ISHLAB CHIQUISH VA ROC
TAHLILI ASOSIDA VALIDATSIYA**

Khamdamov I.B.

**Buxoro davlat tibbiyot universiteti, Buxoro, O‘zbek-
iston**

ANNOTATSIYA

Ushbu tadqiqotda metabolik sindromga ega bemorlarda bariatrik jarrohlik natijalarini oldindan baholash uchun 8 parametrdan iborat kompleks ball tizimi ishlab chiqildi. Parametrlar BMI, HOMA-IR, HbA1c, C-peptid, GERD, NAJBP, me‘da o‘qi va hajmini o‘z ichiga oladi. 180 bemor ma‘lumotlari asosida retrospektiv tahlil qilindi, keyinchalik 60 bemorda prospektiv validatsiya o‘tkazildi. ROC tahlil natijalariga ko‘ra, modelning AUC ko‘rsatkichi 0.86 ni tashkil etdi. 9 ball va undan yuqori bo‘lgan bemorlar 4.3 marta ko‘proq muvaffaqiyatli natijalarga erishgan. Ushbu tizim individual yondashuv asosida jarrohlik turini aniqlash va natijalarni bashorat qilishda yuqori amaliy foydaga ega ekanini ko‘rsatdi.

Kalit so‘zlar: Metabolik sindrom, bariatrik jarrohlik, ball tizimi, prognoz modeli, ROC tahlili, individualizatsiya.

**РАЗРАБОТКА И ROC-ВАЛИДАЦИЯ ШКАЛЫ
ПРЕДОПЕРАЦИОННОЙ ОЦЕНКИ ДЛЯ
ПРИНЯТИЯ ХИРУРГИЧЕСКОГО РЕШЕНИЯ У
БОЛЬНЫХ С МЕТАБОЛИЧЕСКИМ
СИНДРОМОМ**

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АННОТАЦИЯ

Целью данного исследования явилось создание и валидация предоперационной шкалы для прогнозирования успеха бариатрического вмешательства у пациентов с метаболическим синдромом. В модель включено 8 параметров: ИМТ, HOMA-IR, HbA1c, уровень С-пептида, наличие ГЭРБ, НАЖБП, отклонение оси желудка и объём желудка по КТ. На ретроспективной выборке из 180 пациентов выявлены значимые предикторы, а на 60 новых пациентах проведена валидация. ROC-анализ показал высокую прогностическую способность модели (AUC=0.86), при этом балл ≥ 9 ассоциировался с 4,3-кратным увеличением вероятности успеха. Модель оказалась эффективной для стратификации риска и обоснованного выбора между антирефлюксной LSG и индивидуализированной OAGB. Представленная шкала может служить инструментом персонализированного планирования в метаболической хирургии.

Ключевые слова: Метаболический синдром, бариатрическая хирургия, шкала оценки, ROC-анализ, прогноз, персонализация.