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Perioperative Outcome Prediction in Adrenalectomy: Why MAP Score Matters More Than BMI?

Adrenalektomide Perioperatif Sonuçların Öngörülmesi: Neden MAP Skoru BMI'dan Daha Önemlidir?

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Abstract

Background: This study aimed to evaluate the clinical utility of the Mayo Adhesive probability (MAP) score in predicting surgical difficulty in adrenalectomy and to compare its performance with body mass index (BMI).

Materials and Methods: We retrospectively analyzed 161 patients who underwent adrenalectomy for adrenal adenomas between 2015 and 2024. Patients were categorized into low (0-1) and high (2-5) MAP score groups, and into three BMI categories (<25, 25-30, >30 kg/m²). Operative time, estimated blood loss, hospital stay, and drain removal time were compared across groups.

Results: Patients with high MAP scores had significantly longer operative times (140 vs. 100 minutes, p<0.001), greater blood loss (80 vs. 50 mL, p<0.001), longer hospital stays (8 vs. 7 days, p=0.010), and delayed drain removal (4 vs. 3 days, p<0.001). No significant differences were observed across BMI categories.

Conclusions: The MAP score is a practical preoperative tool for risk stratification in adrenalectomy, providing more reliable prediction of surgical complexity than BMI.

Keywords: Adrenalectomy, Mayo Adhesive probability score, Body mass index, Perioperative outcomes

Öz

Amaç: Bu çalışma, adrenalektomide cerrahi zorluğu öngörmede Mayo Adezif olasılık (MAP) skorunun klinik yararını değerlendirmeyi ve performansını vücut kitle indeksi (VKİ) ile karşılaştırmayı amaçlamıştır.

Materyal ve metod: 2015-2024 yılları arasında adrenal adenom nedeniyle adrenalektomi uygulanan 161 hasta retrospektif olarak analiz edildi. Hastalar preoperatif MAP skoruna göre düşük (0-1) ve yüksek (2-5) gruplara, VKİ değerine göre ise üç kategoriye (<25, 25-30, >30 kg/m²) ayrıldı. Operasyon süresi, tahmini kan kaybı, hastanede yatış süresi ve dren çekilme zamanı gruplar arasında karşılaştırıldı.

Bulgular: Yüksek MAP skoruna sahip hastalarda operasyon süresi (140 vs. 100 dakika, p<0,001), kan kaybı (80 vs. 50 mL, p<0,001), hastanede yatış süresi (8 vs. 7 gün, p=0,010) ve dren çekilme zamanı (4 vs. 3 gün, p<0,001) anlamlı olarak daha fazlaydı. VKİ kategorileri arasında ise bu parametreler açısından anlamlı fark saptanmadı.

Sonuç: MAP skoru, adrenalektomide cerrahi zorlukların öngörülmesinde pratik bir preoperatif risk sınıflama aracı olup, cerrahi karmaşıklığın öngörülmesinde VKİ'ye kıyasla daha güvenilir sonuçlar sağlamaktadır.

Anahtar Kelimeler: Adrenalektomi, Mayo Adezif olasılık skoru, Perioperatif sonuçlar, Vücut kitle indeksi

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Introduction

Laparoscopic adrenalectomy (LA) has become the standard approach for the management of benign adrenal tumors (1). Despite its widespread adoption and demonstrated safety, certain patient factors can complicate adrenalectomy. In particular, the global rise in obesity has raised concerns about the impact of excessive adiposity on surgical difficulty. However, the evidence regarding obesity and LA outcomes is mixed. For example, Ishihara et al. found no significant differences in operative time, blood loss, or complication rates between obese and non-obese patients undergoing transabdominal LA (2). In contrast, a recent propensity-matched study reported that obese patients had significantly longer operative times and greater intraoperative blood loss in retroperitoneal LA (RLA) (3). These conflicting findings suggest that body mass index (BMI)-a global measure of body fat - may not fully capture the anatomic challenges posed by obesity in adrenal surgery. In fact, studies in adrenalectomy have begun to highlight more specific anthropometric predictors: Pearlstein et al. (4) showed that periadrenal fat volume (measured on imaging) was a stronger independent predictor of operative time than BMI, and Erbil et al. (5) similarly reported that retroperitoneal fat area was more predictive of surgical difficulty than BMI in adrenalectomy.

The Mayo Adhesive probability (MAP) score is a radiologic scoring system originally developed in kidney surgery to quantify adherent perinephric fat (APF) on preoperative imaging (6). MAP combines measurements of posterior perinephric fat thickness and the degree of perinephric fat “stranding” or inflammation on CT to assign a score from 0-5. Higher MAP scores have been validated as predictors of difficult dissection and longer operative times in partial nephrectomy (6).

Given the adrenal glands’ anatomic location within the perirenal fat, it is plausible that MAP could similarly predict the complexity of adrenalectomy. Indeed, preliminary studies in adrenal surgery suggest that MAP is prognostically valuable. Yuan et al. (7) found that patients with higher MAP scores had significantly longer operative times, greater blood loss, and longer drainage duration in RLA. Likewise, Kira et al. (8) reported that MAP >0 was independently associated with prolonged operative time in LA. In a large cohort of benign retroperitoneal adrenalectomies, Chen et al. (9) demonstrated a graded increase in operative time and blood loss with rising MAP scores; MAP was the only independent predictor of perioperative outcomes in multivariable analysis. More recently, Miyamoto et al. (10) showed that a MAP ≥3 was associated with significantly increased intraoperative blood loss and identified high-MAP patients as high-risk for bleeding. These studies reinforce that MAP captures aspects of local fat anatomy that are clinically relevant.

Given the limitations of BMI and the promising data on MAP, the present study aimed to directly compare MAP score versus BMI as predictors of perioperative outcomes in adrenalectomy. We hypothesized that MAP - by quantifying the thickness and adhesiveness of perinephric fat on imaging - would more accurately predict operative difficulty and perioperative morbidity than BMI. Clarifying the relative utility of MAP and BMI in adrenalectomy could improve preoperative risk stratification and surgical planning.

Materials and Methods

This single-center retrospective study included all consecutive adult patients who underwent adrenalectomy [open, laparoscopic transperitoneal (TLA), or laparoscopic retroperitoneal (RLA)] between 2015 and 2024 at our institution. All included patients had preoperative contrast-enhanced abdominal CT and histologically confirmed adrenal adenomas. We excluded patients with incomplete records, non-adenoma adrenal pathology, prior ipsilateral adrenal surgery, or missing preoperative imaging. The study was approved by the Izmir Katip Celebi University Ethics Committee approval no: 0148, date: October 17, 2024 and data were handled in accordance with the Declaration of Helsinki; written informed consent was obtained per institutional guidelines.

The collected variables included demographic data (age, sex), comorbidities (hypertension, diabetes mellitus, smoking status), and preoperative laboratory parameters (hemoglobin, hematocrit, creatinine, albumin levels). Tumor-related characteristics such as size and laterality were recorded. BMI (kg/m²) was calculated for all patients. Perioperative data collected included the type of surgical approach (open, TLA or RLA), operative time, estimated intraoperative blood loss, length of hospital stay, and time to drainage tube removal. Additionally, changes in postoperative laboratory measures were documented.

MAP Score Assessment

Two experienced urologists, blinded to patient outcomes, independently reviewed each preoperative CT scan to calculate the MAP score. The MAP score was determined by adding points for (a) posterior perinephric fat thickness (0 points if <1.0 cm, 1 point if 1.0-2.0 cm, and 2 points if ≥2.0 cm) and (b) perinephric fat stranding on CT (0 points for none, 2 points for mild, and 3 points for severe). The CT slice at the level of the renal vein was used for consistency (10). Any discrepancies were resolved by consensus. Patients were stratified into two MAP groups: “low MAP” (score 0-1) and “high MAP” (score 2-5), based on thresholds reported to separate minimal versus significant APF (11). The calculation method of the MAP score is illustrated with representative CT images in Figure 1 to provide practical guidance on its assessment. For comparison, patients were also grouped by BMI (<25, 25-30, and >30 kg/m2) to assess outcomes across obesity categories (12).

Statistical Analysis

All statistical analyses were performed using Jamovi software (version 2.6.25). Continuous variables were expressed as mean ± standard deviation or median (range) depending on distribution, and categorical variables as numbers and percentages. The Shapiro-Wilk test was used to assess normality. Comparisons between two groups (e.g., low vs. high MAP) were conducted with the Mann-Whitney U test for continuous variables and chi-square test for categorical variables. For comparisons across more than two BMI categories, the Kruskal-Wallis test with Dunn's post-hoc analysis and Bonferroni correction was applied. A two-tailed p value <0.05 was considered statistically significant.

Results

A total of 161 patients were included in this study. The mean age was 62.98±9.30 years, with 95 patients (59%) being male. Among them, 58 patients (36.02%) underwent open surgery, 59 patients (36.6%) underwent TLA, and 44 patients (27.4%) underwent RLA. The demographic and adrenal mass characteristics of the patients are summarized in Table 1.

Table 1. Patients and adrenal mass characteristics

Characteristic	**All patients (n=161)**
Age (mean ± SD)	62.98±9.30 years
Sex (%)	
Male	95 (59)
Female	66 (41)
Body mass index, kg/m2	25.8 (13.28-46.07)
Body mass index distribution, n (%)	
<25 kg/m^2	62 (38.5)
25-30 kg/m^2	57 (35.4)
>30 kg/m^2	42 (26.1)
Preoperative hemoglobin (mean ± SD) (g/dL)	12.78±2.23
Preoperative hematocrit (mean ± SD) (%)	38.96±6.5
Preoperative creatinine [median (min-max)] (mg/dL)	0.9 (0.54-6.31)
Preoperative albumin [median (min-max)] (g/dL)	3.8 (1.8-5)
Diabetes mellitus n (%)	45 (28)
Hypertension n (%)	73 (45.3)
Smoking n (%)	95 (59)
Tumor size (mm)	40 (9-190)
Mayo Adhesive probability score [median (min-max)]	1 (0-5)
Mayo Adhesive probability score distribution, n (%)	
Low	83 (51.6)
High	78 (48.4)
Type of operation	
Open	58 (36)
TLA	59 (36.6)
RLA	44 (27.4)

TLA: Transperitoneal laparoscopic adrenalectomy, RLA: Retroperitoneal laparoscopic adrenalectomy, SD: Standard deviation

When stratified by MAP score, patients in the high MAP group (scores 2-5) demonstrated significantly longer operative times (median: 140 vs. 100 minutes, p<0.001), higher estimated blood loss (80 vs. 50 mL, p<0.001), and longer hospital stays (8 vs. 7 days, p=0.010) compared to those in the low MAP group (scores 0-1). Additionally, the high MAP group exhibited a longer time to drain removal (4 vs. 3 days, p<0.001) and a greater postoperative increase in serum creatinine (+0.165 vs. +0.045 mg/dL, p<0.001). Comparisons of MAP scores with perioperative outcomes are presented in Table 2.

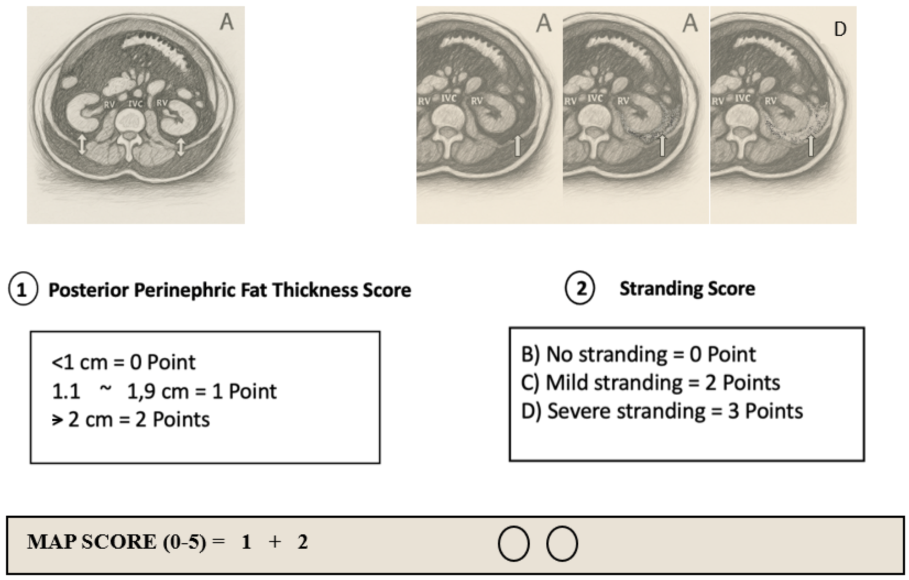

Figure 1. Calculation of the Mayo Adhesive probability (MAP) Score using preoperative axial CT images. Representative axial CT images at the level of the renal vein demonstrate the two MAP score components: (A) posterior perinephric fat thickness measurement (indicated by calipers) and (B, C and D) perinephric fat stranding severity (highlighted by arrows). The MAP score is calculated by summing the points for fat thickness (0-2 points) and fat stranding (0-3 points), resulting in a total score ranging from 0 to 5. Higher MAP scores indicate increased perinephric fat adhesiveness, which may predict greater surgical complexity during adrenalectomy

CT: Computed tomography

Table 2. Perioperative outcomes according to Mayo Adhesive probability score

Perioperative outcomes	**MAP low (n=83)**	**MAP high (n=78)**	**p**
Operative time (min)	100 (51-294)	140 (58-282)	<0.001*
Estimated blood loss (mL)	50 (10-200)	80 (20-200)	<0.001*
Change in laboratory measures			
Hemoglobin (g/dL)	1.2 (-2.1-3.7)	1.3 (-3.3- 5.2)	0.838*
Creatinine (mg/dL)	+0.045 (0.65-0.9)	+0.165 (3.09-1.8)	<0.001*
Length of hospital stay (day)	7 (3-33)	8 (3-68)	0.010*
Drainage tube removal time (day)	3 (1-10)	4 (1-42)	<0.001*
Type of operation	n (%)	n (%)	0.257**
Open	29 (34.9)	29 (37.2)	
TLA	35 (42.2)	24 (30.8)	
RLA	19 (22.9)	25 (32.1)	

MAP: Mayo Adhesive probability, TLA: Transperitoneal laparoscopic adrenalectomy, RLA: Retroperitoneal laparoscopic adrenalectomy

*Mann-Whitney U test, **Chi-squared test

In contrast, when patients were categorized according to BMI, no statistically significant differences were observed across BMI groups in operative time, estimated blood loss, length of hospital stay, or drain removal time (p>0.05 for all comparisons). A non-significant trend toward increased operative times and blood loss was observed with higher BMI categories; however, these differences did not reach statistical significance (Table 3).

Table 3. Perioperative outcomes according to body mass index				
Perioperative outcomes	**BMI <25 kg/m²** **(n=62)**	**BMI 25-30 kg/m²** **(n=57)**	**BMI >30 kg/m²** **(n=42)**	**p**
Operative time (min)	109 (61-294)	125 (51-282)	123.5 (54-254)	0.115
Estimated blood loss (mL)	50 (10-200)	50 (20-150)	65 (20-200)	0.156
Changes in laboratory measures				
Hemoglobin (g/dL)	1.4 (-1-3.7)	1.1 (-3.3-5.2)	0.9 (-3.2-3.1)	0.193
Creatinine (mg/dL)	+0.1 (0.91- 0.65)	+0.14 (3.09- 1.8)	+0.06 (0.87- 0.56)	0.342
Length of hospital stay (day)	7 (3-19)	7 (3-68)	6 (3-22)	0.181
Drainage tube removal time (day)	3 (1-7)	4 (1-42)	4 (1-10)	0.223
BMI: Body Mass Index Kruskal-Wallis test (with Dunn's post-hoc analysis and Bonferroni correction)				

In a subgroup analysis focusing on patients with high MAP scores, we further evaluated perioperative outcomes according to the type of surgical approach (open, TLA and RLA). RLA demonstrated numerically shorter operative times, and hospital stays compared to TLA and open approaches; however, these differences did not reach statistical significance (p=0.091). Data on patients with high MAP scores stratified by surgical approach are presented in Table 4.

Table 4. Perioperative outcomes according to operation type in patients with high MAP score				
Perioperative outcomes	**Operation type**			**p**
	Open (n=29)	TLA (n=24)	RLA (n=25)	
Operative time (min)	131 (58-195)	155 (66-282)	152 (60-232)	0.149*
Length of hospital stay (day)	8 (5-19)	8 (3-21)	6 (3-68)	0.134*
Drainage tube removal time (day)	5 (3-8)	4 (1-7)	4 (2-42)	0.091*
Kruskal-Wallis test				

Discussion

In this study, MAP was a strong predictor of perioperative complexity in adrenalectomy, while BMI showed no significant association with outcomes. Patients in the high MAP group (score 2-5) experienced markedly longer operative times, increased blood loss, and longer drain duration and hospital stays than patients in the Low MAP group. In contrast, stratifying patients by BMI revealed no statistically significant differences in operative time, blood loss, or length of stay across BMI categories. These findings suggest that MAP more accurately captures the anatomic challenges of adrenal dissection than BMI.

Our findings align with previous studies. Chen et al. (9) showed that higher MAP scores were associated with longer operative times and greater blood loss during RLA. Unlike Chen's focus on RLA alone, our cohort included open, TLA, and retroperitoneal approaches, confirming MAP's predictive value across techniques. We also assessed recovery parameters, including drainage duration, hospital stay, and renal function. By directly comparing MAP with BMI, we demonstrated that BMI does not predict perioperative outcomes, whereas MAP consistently does.

Similarly, Yuan et al. (7) reported that higher MAP scores were associated with longer operative time, greater blood loss, and delayed drain removal in RLA. In contrast, we analyzed a broader surgical spectrum and compared MAP directly with BMI, again showing that BMI was not predictive while MAP consistently was. We also assessed recovery outcomes such as hospital stay and renal function, underscoring MAP's wider clinical relevance.

Kira et al. (8) found that MAP >0 was associated with longer operative time in functional tumor adrenalectomy. We expanded these findings by showing that MAP predicts blood loss and recovery outcomes and outperforms BMI as a tool for risk stratification.

Miyamoto et al. (10) retrospectively analyzed 103 LA patients and found that higher MAP scores were linked to greater blood loss, male sex, and higher BMI. They concluded that patients with MAP ≥3 or malignant tumors were at increased risk of bleeding and required stricter perioperative management. These findings parallel ours, supporting MAP as a reliable preoperative marker of surgical difficulty and bleeding risk in adrenalectomy. Taken

together, these studies and our results indicate that perinephric fat characteristics, as quantified by MAP, have tangible impacts on adrenalectomy difficulty and should inform surgical planning.
By contrast, BMI proved to be a poor surrogate for perinephric fat. Consistent with Ishihara et al., who showed equivalent outcomes for obese (BMI ≥25) and non-obese patients, we found no significant association between BMI and operative outcomes (2). This finding held even after categorizing BMI into underweight/normal, overweight, and obese ranges. This likely reflects BMI's limitation in capturing fat distribution, as patients with the same BMI may have very different visceral or perirenal fat. Previous research has underscored this point: Wang et al. (13) reported that retroperitoneal fat area (as measured on imaging) was a far more important determinant of operative time in LA than BMI. Pearlstein et al. (14) similarly showed that periadrenal fat volume on CT was a better independent predictor of extended operative time in retroperitoneal adrenalectomy than BMI. In our analysis, we reaffirmed this: although higher BMI showed a non-significant trend toward longer operative times and greater blood loss, only MAP score reached statistical significance. Thus, MAP appears to capture the surgical-relevant component of obesity (APF), whereas BMI does not.
Our findings confirm and extend the concept that MAP is a valuable preoperative tool across different urologic surgeries. Originally described by Davidiuk et al. (6) for partial nephrectomy, the MAP score has now been demonstrated to predict operative difficulty in adrenalectomy. Notably, the adrenal glands lie in close proximity to the kidney and are enveloped by perinephric fat. Dense, sticky adipose tissue in this area obscures tissue planes, reduces visibility, and complicates dissection (10,15). By quantifying fat thickness and stranding, MAP provides a reproducible estimate of surgical difficulty (16,17). Our results extend this by showing that high MAP is associated with longer surgery, more bleeding, and delayed recovery. Clinically, this suggests that surgeons should anticipate greater intraoperative challenges and potential for renal stress (e.g. increased serum creatinine, as we observed) in high-MAP patients, and may wish to adjust their operative strategy accordingly.
We also examined whether surgical approach modified the influence of MAP. Prior work suggests that the retroperitoneal approach may offer advantages in cases with adherent fat, since it provides direct access to the adrenal without traversing the peritoneal cavity (15). In our subgroup analysis of high-MAP patients, there was a non-significant trend toward shorter operative times and stays with retroperitoneal access compared to TLA or open approaches. However, these differences did not reach statistical significance, perhaps due to limited sample size. Interestingly, open adrenalectomy had the shortest median operative time in our cohort, likely reflecting the absence of laparoscopic port placement and the familiarity of surgeons with the open technique. Nevertheless, given the well-established benefits of minimally invasive surgery (less pain, quicker recovery), open surgery is generally reserved for very large or invasive tumors (3,18). Our data suggest that, even in difficult (high-MAP) cases, LA remains feasible, but that surgeons should be aware of the potential need for longer operative times and careful dissection in adipose patients.
In summary, this study demonstrates that the MAP score -rather than BM- should be utilized for preoperative risk assessment in adrenalectomy. The MAP score can be easily calculated from routine preoperative CT scans and provides valuable insights into the 'stickiness' of perinephric fat, which directly impacts the complexity of dissection and the risk of intraoperative blood loss. Recognizing a high MAP score preoperatively can help surgical teams anticipate challenges and prepare with additional time, hemostatic tools, and the most suitable approach. Incorporating MAP assessment into routine preoperative planning may therefore enhance patient counseling, operative efficiency, and overall surgical outcomes in adrenal surgery.
This study has several limitations that should be acknowledged. First, its retrospective and single-center design may introduce selection bias, limit generalizability, and reflect local surgical practices, which may not fully represent broader populations or other healthcare systems. Although all surgeries were performed by experienced urologists, variability in surgeon experience, decision-making, and subtle differences in surgical technique may have influenced operative outcomes, which were not uniformly quantifiable in this analysis. Second, while the MAP score effectively reflects perinephric fat characteristics on preoperative CT, it does not capture other factors influencing surgical difficulty, such as tumor vascularity, gland adherence due to prior inflammation or subclinical hemorrhage, anatomical variations, or peritumoral fibrosis, all of which can impact operative complexity and blood loss. Additionally, the MAP score focuses primarily on the posterior perinephric fat plane and may not account for lateral or anterior adhesions that can challenge exposure during adrenalectomy, particularly in large tumors. Third, although we assessed perioperative outcomes as surrogate measures of surgical complexity, we did not use validated intraoperative grading scales that could provide a more objective assessment of dissection complexity. Incorporating structured intraoperative scoring by multiple blinded observers in future studies would strengthen objectivity and reproducibility. Fourth, our sample size, particularly in subgroup analyses across surgical approaches in high-MAP patients, may have been underpowered to detect statistically significant differences. Larger multicenter studies are needed to confirm whether surgical approach modifies the impact of high MAP scores on operative outcomes and to validate the findings across diverse patient cohorts. Finally, although we controlled for tumor size in the analysis, we did not stratify outcomes by functional versus non-functional tumors, which may influence

operative planning and complexity due to differences in vascularity and friability. Furthermore, we did not analyze long-term outcomes such as postoperative renal function, delayed complications, or quality of life, which could provide additional insights into the broader implications of MAP scoring in adrenal surgery.

Future prospective, multicenter studies utilizing standardized intraoperative difficulty grading, controlling for tumor functionality, and incorporating long-term follow-up are warranted to validate the routine use of MAP scoring in adrenalectomy and to determine its role in personalized surgical planning.

Conclusion

Our data indicate that the MAP score is a powerful predictor of surgical complexity in adrenalectomy, whereas BMI is not. Patients with high MAP scores (2-5) had significantly longer operative times, greater blood loss, and longer recovery courses than those with low scores. These results underscore that local perinephric fat characteristics -rather than overall body habitus-drive operative difficulty in adrenal surgery. In clinical practice, routine preoperative MAP assessment can enhance risk stratification and patient counseling. A high MAP score should alert the surgical team to anticipate a challenging dissection, allocate additional operative time, ensure the availability of hemostatic devices, and consider the most appropriate surgical approach. Incorporating MAP into standard surgical planning may therefore improve operative efficiency, optimize team preparation, and lead to better perioperative outcomes. Future prospective studies should validate MAP-guided decision-making and explore technical strategies to mitigate the challenges posed by adherent fat.

Ethical Approval: *This study was approved by the Health Research Ethics Committee of İzmir Katip Çelebi University (approval no: 0148, date: October 17, 2024).*

Author Contributions:

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Design: E.M.Y., S.Ö.

Data acquisition: O.K.

Analysis and interpretation: E.M.K.

Writing manuscript: E.M.Y., S.N.G.

Critical revision of manuscript: S.N.G., Y.A.

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