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Resected gastric volume/ number of staplers fired ratio as a tool in predicting complication and midterm results in sleeve gastrectomy

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Laparoscopic sleeve gastrectomy is a restrictive surgery that aims to decrease the gastric volume of the patient. This study hypothesized that a higher resected gastric volume to the number of fired staplers ratio is associated with improved postoperative 12th-month outcomes. To analyze the effects of resected gastric volume to the number of fired staplers ratio on postoperative results in patients who underwent sleeve gastrectomy. University Hospital, Istanbul, Türkiye. We analyzed the data of 407 patients who underwent laparoscopic sleeve gastrectomy between 2018 and 2022. The primary outcome was the effect of resected gastric volume to the number of fired staplers ratio on excess weight loss at 12 months postoperatively. A total of 407 patients were included in the study. The higher resected gastric volume to the number of fired staplers ratio was associated with higher excess weight loss in the postoperative 12th month, while no significant effect was found on complications ($p = 0.001$ and $p = 0.785$, respectively). This study revealed resected gastric volume to the number of fired staplers ratio could be used to predict weight loss. Further studies should examine the effect of resected gastric volume to number of fired staplers ratio on postoperative complications.

Keywords Laparoscopic sleeve gastrectomy, Resected gastric volume, Staple firing number, Ratio, Complications

Obesity is a common disease responsible for different systemic disorders[1]. Bariatric surgery is a last-resort treatment option in patients with obesity, refractory to medical modalities, with laparoscopic sleeve gastrectomy (LSG) being the most commonly applied bariatric procedure[2]. Although its benefits are testified, it's not a magical touch without any failures or complications. It's said that > 25% of patients regain weight, and up to 5% experience operative complications, including stapler line leakage (SLL), hemorrhage, or gastric stricture[3,4].

Since weight loss is a multifactorial process including metabolic, psychological, and surgical factors, it's challenging to predict the outcome of the surgery. Thus, different elements are widely researched to predict outcomes[5–7]. LSG is a surgery defined under the umbrella term of restrictive surgery. The initial theory behind the operation is decreasing the gastric volume. Therefore, resected gastric volume (RGV) is a crucial factor affecting the outcome of the surgery[8].

The number of staplers fired (SF) is an operative parameter directly affected by the patient characteristics, dimensions of the stomach, and the surgeon himself. Its relationship with short-term complications is reported, but there are no significant data on its midterm bariatric results[9,10].

This study includes largest dataset of the patients operated on by a single surgeon in a single center. Our study reveals the relationship between the ratio of RGV/SF and clinical outcomes.

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Materials and methods

Data collection

Data from the patients who underwent LSG between 2018 and 2022 in our hospital were recorded prospectively and collected retrospectively following the institutional board approval from Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (KAEK/2023.03.06). The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request. Consent forms were taken from the institution and the patients according to the editorial and publishing policies. All methods were performed following the relevant guidelines and regulations. 407 patients operated by the same surgeon who completed 12 months of follow-up and gave written consent to participate in the study were included in the study.

Surgical technique

All patients were operated on using three trocars (12 mm, 10 mm, 5 mm). All patients underwent the same procedure. The greater curvature dissection was performed using LigaSure™ [Medtronic, (Dublin, Ireland)], starting 3 cm proximal to the pylorus until the left hiatal crus was exposed. A 38 Fr bougie was positioned along the lesser curvature of the stomach to guide the gastrectomy. Gastrectomy was performed starting 3 cm from the pylorus and continuing to within 1–2 cm of the esophagogastric junction, using a Tri-Staple™ [Medtronic, (Dublin, Ireland)] with purple cartridges. Hemostasis was achieved with metal clips at bleeding sites along the staple line. No staple line reinforcement was applied. The staple line was checked with a methylene blue leak test, and a Jackson-Pratt drain was placed along the staple line in all patients. Only the skin at the trocar insertion sites was closed. The RGV was measured by insufflating the specimen with CO2 through the antrum until the internal pressure reached 10 mmHg. The amount of gas used was recorded as mL.

Statistical analysis

Patients were divided into groups according to the RGV, SF, and RGV/SF ratio. Percent excess weight loss (%EWL) indicated treatment success. It was calculated by *[(Preoperative Weight-Postoperative Weight)/(Preoperative Weight-Ideal Body Weight)]x100*. Patients with ≥%50 EWL were regarded as efficaciously treated. Receiver operator characteristics (ROC) analysis was performed to determine the optimal RGV and RGV/SF cut-off values. 725 mL and 103.57 mL/n were determined, respectively.

The Fisher's exact test and chi-square (x^2) test were used to compare the categorical variables between the two groups. Kolmogorov Smirnov and Shapiro-Wilk tests were performed to analyze the normal distribution of the data. Independent samples T-test and analysis of variance were performed to investigate the normal distributing data, and Mann Whitney-U and Kruskal Wallis tests were performed to compare the non-normal distributing data. Univariate and multivariate regression analyses were performed to analyze the %EWL and complication indicators. $p < 0.05$ was assumed to be statistically significant.

Results

Baseline characteristics

A total of 407 patients were included in this study. 391 (96.1%) patients were female. The rate of female patients was significantly higher in the < 725mL RGV group and the < 123.57 RGV/SF group ($p = 0.042$ and $p = 0.022$, respectively).

The mean age was 35.29. The patients with > 725mL RGV, > 123.57 RGV/SF, and ≥ 50% %EWL had a higher mean age ($p < 0.001$, $p = 0.002$, and $p = 0.008$, respectively). The mean age of patients in the 5 SF group was lower than 6 SF and > 6 SF groups ($p = 0.018$).

The mean preoperative BMI was 45.57 kg/m^2. Patients with < 50% %EWL and < 725mL RGV had higher BMI ($p = 0.009$ and $p = 0.002$, respectively). On the first preoperative visit, 230 (56.5%) patients had at least one obesity-related comorbidity.

The rate of patients with comorbidities was higher in those with ≥ 50% %EWL and those who experienced any complications ($p = 0.01$ and $p = 0.002$, respectively). The rate of any obesity-related disease was lower in the 5 SF group ($p < 0.001$). The baseline characteristics of the patients and the relationship between the groups are outlined in Table 1.

Operative and complication outcomes

The mean RGV was 766mL. Higher RGV/SF ratio, experiencing complication, and > 6 SF were associated with increased RGV ($p < 0.001$, $p = 0.031$, and $p < 0.001$, respectively).

The mean SF was 6.05. There was a statistically significant but clinically insignificant increase in SF in patients with < 50% %EWL and experienced complications ($p < 0.001$, and $p < 0.001$, respectively).

The mean RGV/SF ratio was 127.46. Patients with > 725mL RGV and ≥ 50% %EWL were prone to have an increased RGV/SF ratio ($p < 0.001$ and $p < 0.001$, respectively).

Forty-two (10.3%) patients experienced complications in total. 24 (57.1%) of these were bleeding, 15 (35.7%) were nausea-vomiting, and 3 (7.2%) were gastric twists or stenosis. The details of operative and complication outcomes are outlined in Table 2.

Weight loss outcomes

The mean BMI at the 6th month postoperatively was 33.53 kg/m^2, and the mean BMI loss (%BMIL) since the operation was 26.42%. There was no significant difference in %BMIL at the 6th month postoperatively. Patients with < 725mL RGV were prone to have a higher BMI at the 6th month postoperatively, but there was no difference in %BMIL ($p = 0.017$ and $p = 0.615$, respectively).

	Female, *n*(%)	Age, mean ± SD	Initial BMI mean ± SD	Comorbidity, *n*(%)
RGV < 725 ml (203)	199 (98.1)	33,42 ± 10,09	46,23 ± 4,72	106 (52,2)
RGV > 725 ml (204)	192 (94.1)	37,16 ± 11,01	44,92 ± 5,27	124 (60,8)
p-value	***0,042**[a]*	***< 0,001**[b]*	***0,009**[b]*	*0,081[a]*
RGV/SF < 103,57 (163)	161 (98.8)	33,29 ± 10,99	45,76 ± 4,76	99 (60,7)
RGV/SF > 103,57 (244)	230 (94.3)	36,64 ± 10,33	45,45 ± 5,22	131 (53,7)
p-value	***0,022**[a]*	***0,002**[b]*	*0,539[b]*	*0,160[a]*
< 50% %EWL (36)	34 (94.4)	30,75 ± 10,48	48,69 ± 5,88	13 (36,1)
≥ 50% %EWL (371)	357 (96.2)	35,74 ± 10,65	45,27 ± 4,85	217 (58,5)
p-value	*0,422[c]*	***0,008**[b]*	***0,002**[b]*	***0,010**[a]*
No Complication (365)	350 (95.9)	35,35 ± 10,69	45,68 ± 5,10	197 (54)
Had Complication (42)	41 (97.6)	34,86 ± 11,03	44,62 ± 4,40	33 (78,6)
p-value	*0,494[c]*	*0,780[b]*	*0,151[b]*	***0,002**[a]*
SF = 5 (95)	91 (95.8)	32,58 ± 10,59	44,56 ± 4,45	39 (41,1)
SF = 6 (202)	195 (96.5)	36,10 ± 11,36	45,85 ± 4,92	115 (56,9)
SF > 6 (110)	105 (95.5)	36,15 ± 9,19	45,93 ± 5,63	76 (69,1)
p-value	*0,884[a]*	***0,018**[d]*	*0,080[d]*	***< 0,001**[a]*

Table 1. The baseline characteristics of the patients and the relationship between the groups. RGV: Resected gastric volume; SF: Staplers fired; SD: Standard deviation; EWL: Excess weight loss; BMI: Body mass index. [a]: Pearson's chi-squared test; [b]: Independent t-test for two samples; [c]: Fisher's exact test; [d]: Analysis of variance.

	RGV(mL), mean ± SD	SF, mean ± SD	RGV/SF, mean ± SD	Complications, *n*(%)	Bleeding, *n*(%)	Nausea, *n*(%)	Twist, *n*(%)
RGV < 725 ml (203)		6 ± 0,67	91,34 ± 17,14	18 (8,9)	2 (1)	13 (6,4)	3 (1,5)
RGV > 725 ml (204)		6,11 ± 0,80	163,41 ± 46,92	24 (11,8)	22 (10,8)	2 (1)	0 (0)
p-value		*0,124[b]*	***< 0,001**[b]*	*0,337[a]*	***< 0,001**[a]*	***0,004**[a]*	*0,123[c]*
RGV/SF < 103,57 (163)	525,46 ± 110,05	6,11 ± 0,66		16 (9,8)	0 (0)	13 (8)	3 (1,8)
RGV/SF > 103,57 (244)	927,46 ± 285,60	6,01 ± 0,79		26 (10,7)	24 (9,8)	2 (0,8)	0 (0)
p-value	***< 0,001**[b]*	*0,190[b]*		*0,785[a]*	***< 0,001**[a]*	***< 0,001**[a]*	*0,064[c]*
< 50% %EWL (36)	686,11 ± 191,09	6,64 ± 0,49	103,84 ± 28,51	3 (8,3)	2 (5,6)	0 (0)	1 (2,8)
≥ 50% %EWL (371)	774,26 ± 312,11	5,99 ± 0,74	129,75 ± 51,57	39 (10,5)	22 (5,9)	15 (4)	2 (0,5)
p-value	*0,097[b]*	***< 0,001**[b]*	***< 0,001**[a]*	*0,477[c]*	*0,642[c]*	*0,243[c]*	*0,243[c]*
No Complication (365)	753,42 ± 295,75	5,99 ± 0,74	126,84 ± 50,72				
Had Complication (42)	879,76 ± 353,91	6,57 ± 0,55	132,91 ± 48,61				
p-value	***0,031**[b]*	***< 0,001**[b]*	*0,461[b]*				
SF = 5 (95)	735,26 ± 320,89		147,05 ± 64,18	0 (0)	0 (0)	0 (0)	0 (0)
SF = 6 (202)	715,84 ± 234,41		119,31 ± 39,07	19 (9,4)	6 (3)	13 (6,4)	0 (0)
SF > 6 (110)	886,36 ± 366,73		125,52 ± 51,61	23 (20,9)	18 (16,4)	2 (1,8)	3 (2,7)
p-value	***< 0,001**[b]*		***< 0,001**[d]*	***< 0,001**[a]*	***< 0,001**[a]*	***0,011**[a]*	***0,017**[a]*

Table 2. Operative and complication outcomes. RGV: Resected gastric volume; SF: Staplers fired; SD: Standard deviation; EWL: Excess weight loss. [a]: Pearson's chi-squared test; [b]: Independent t-test for two samples; [c]: Fisher's exact test; [d]: Analysis of variance.

At the 12th month postoperatively, the mean BMI was 28.76 kg/m^2, and the mean %BMIL since the operation was 36.74%. Patients with > 103.57 RGV/SF ratio were prone to have an increased %BMIL ($p = 0.001$). A < 725mL RGV and a < 103.57 RGV/SF ratio were associated with higher BMI at the 12th month follow-up ($p = 0.003$ and $p = 0.002$, respectively).

At the 12th month postoperative follow-up, the mean %EWL was 68.6%. Having < 725mL RGV and > 103.57 RGV/SF ratio were favorable prognostic factors in achieving %EWL ($p = 0.01$ and $p < 0.001$, respectively). The details of weight loss outcomes are outlined in Table 3.

A significant negative and weak correlation exists between the initial BMI and %EWL (r=-0.301, $p < 0.001$). A significant positive and weak correlation was also between RGV and RGV/SF and %EWL ($r = 0.128$, $p = 0.01$ and $r = 0.152$, $p = 0.002$, respectively). While a significant negative correlation was found between the BMI and %EWL at 6 months postoperatively, there was a positive relationship between the %EWL and the %BMIL (r=-0.612, $p < 0.001$ and $r = 0.581$, $p < 0.001$, respectively) at 6 months. At 12 months postoperatively %EWL had a negative correlation with the BMI and a positive correlation with the %BMIL (r=-0.893, p = < 0.001 and $r = 0.85$, $p < 0.001$, respectively).

	6th -Month BMI, mean ± SD	12th -Month BMI, mean ± SD	6th -Month %BMIL, mean ± SD	12th -Month %BMIL, mean ± SD	%EWL, mean ± SD
RGV < 725 ml (203)	34,10 ± 5,23	29,35 ± 4,10	26,24 ± 8,19	36,41 ± 6,92	66,99 ± 13,03
RGV > 725 ml (204)	32,96 ± 4,38	28,18 ± 3,61	26,59 ± 5,52	37,07 ± 6,15	70,21 ± 12,12
p-value	***0,017***[a]	***0,003***[a]	*0,615*[a]	*0,312*[a]	***0,01***[a]
RGV/SF < 103,57 (163)	34 ± 5,44	29,50 ± 4,24	25,76 ± 8,24	35,48 ± 6,73	65,91 ± 13,15
RGV/SF > 103,57 (244)	33,22 ± 4,40	28,27 ± 3,59	26,85 ± 5,95	37,59 ± 6,29	70,40 ± 12,02
p-value	*0,125*[a]	***0,002***[a]	*0,146*[a]	***0,001***[a]	***< 0,001***[a]
No Complication (365)	33,54 ± 4,91	28,74 ± 3,94	26,57 ± 7,06	36,93 ± 6,67	68,77 ± 12,76
Had Complication (42)	33,46 ± 4,35	28,96 ± 3,65	25,02 ± 6,06	35,10 ± 5,08	67,15 ± 11,88
p-value	*0,926*[a]	*0,724*[a]	*0,170*[a]	*0,086*[a]	*0,434*[a]
SF = 5 (95)	32,83 ± 4,01	28,14 ± 3,32	26,12 ± 8,04	36,63 ± 7,01	69,83 ± 13,60
SF = 6 (202)	33,67 ± 4,60	29,08 ± 3,59	26,60 ± 5,98	36,44 ± 5,59	67,72 ± 9,95
SF > 6 (110)	33,88 ± 5,85	28,73 ± 4,79	26,33 ± 7,69	37,40 ± 7,67	69,17 ± 15,88
p-value	*0,256*[b]	*0,153*[b]	*0,159*[b]	*0,459*[b]	*0,352*[b]

Table 3. Weight loss outcomes. RGV: Resected gastric volume; SF: Staplers fired; SD: Standard deviation; EWL: Excess weight loss; BMIL: BMI loss. [a]: Independent t-test for two samples; [b]: Analysis of variance.

	Univariate			Multivariate		
	B	OR (%95 CI)	*p-value*	B	OR (%95 CI)	*p-value*
Age	0,052	1,053 (1,013 – 1,095)	***0,009***	0,056	1,058 (1,011 – 1,107)	***0,015***
Gender (F)	0,405	1,500 (0,327-6,877)	*0,602*			
BMI	-0,125	0,883 (0,827-0,942)	***0,000***	-0,086	0,918 (0,856-0,984)	***0,015***
RGV	0,001	1,001 (1,000–1,003)	*0,099*			
SF	-1,263	0,283 (0,167-0,479)	***0,000***	-1,295	0,274 (0,153-0,490)	***0,000***
RGV/SF	0,015	1,015 (1,005 – 1,025)	***0,004***	0,016	1,016 (1,004 – 1,028)	***0,009***

Table 4. Predictive factors of %EWL. F: Female; BMI: Body mass index; RGV: Resected gastric volume; SF: Staplers fired.

	Univariate			Multivariate		
	B	OR (%95 CI)	*p*	B	OR (%95 CI)	*p*
Age	-,004	0,996 (0,966-1,026)	*0,780*			
Gender (F)	,564	1,757 (0,226-13-648)	*0,590*			
BMI	-,044	0,957 (0,894-1,023)	*0,198*			
RGV	,001	1,001 (1,000–1,002)	***0,012***	0,001	1,001 (1,000–1,002)	*0,198*
SF	1,121	3,067 (1,898-4,956)	***< 0.001***	1,037	2,820 (1,725-4,610)	***< 0.001***
RGV/SF	,002	1,002 (0,996-1,008)	*0,461*			

Table 5. Predictive factors of complications. F: Female; BMI: Body mass index; RGV: Resected gastric volume; SF: Staplers fired.

Predictive factors of %EWL and complications

In achieving the target %EWL, decreased baseline BMI, decreased SF, increased age, and increased RGV/SF ratio were associated with increased achievement. Each increase in the SF reduces the probability of reaching the target %EWL by 72.6%. The details of the analyses are outlined in Table 4.

The results of the regression analysis for the complication experience are summarized in Table 5. In the univariate analysis, RGV and SF were found to be independent factors that affect the complication rate [OR = 1,001 (1,000–1,002), $p = 0.012$ and [OR = 3,067 (1,898-4,956), $p < 0.001$, respectively]. In multivariant analyses of RGV and SF, SF was found to be the most decisive factor affecting the rate of complication [OR = 2,820 (1,725-4,610), $p < 0.001$).

Discussion

Obesity is a global problem that is becoming more common every decade. In 2022, more than 300.000 patients underwent a bariatric operation, and more than 61% were LSG[11]. %EWL is one of the most recognized parameters in the literature for the follow-up of patients in the postoperative period.

A study by Abdallah et al.[6] stated that patients lose 63.8% of their extensive weight in one year following the LSG. In our research, the %EWL was higher than in the before mentioned study in all groups, and there was a significant difference between the RGV and RGV/SF subgroups. In addition to the 12-month postoperative %EWL, the %BMIL at both 6 and 12 months was analyzed to monitor the total weight loss and change in the obesity grade of the patients. We reported that the %BMIL at 6 months wasn't associated with the RGV, RGV/SF ratio, or SF.

SLL and hemorrhage are the most common complications of LSG, with a higher risk of mortality. It's reported that SLL is seen in 0–3% of the patients, and hemorrhage is seen in 0–8%[12]. SF is noted as one of the significant factors of SLL[13]. The significance of SF is controversial in predicting complications. Major et al.[9]said that with every increase in SF, the risk of complication is multiplied by 1.91 (95% CI: 1.09–3.33, $p=0.023$). In a study by Penna et al.[10], ≥7 SF was associated with increased postoperative bleeding and reoperation rates (10.4%, $p=0.0042$, and 10%, $p=0.033$, respectively). We reported that SF was the most contributing factor to the rate of complications. Every increase in SF multiplied the overall complication risk by 2.82 (95% CI:1.73–4.61, $p<0.001$). In our study, the range of the SF was narrower, and the complication rate was higher with more minor Clavien-Dindo scales compared to the study by Major et al.

The RGV and sleeve size volume are other factors affecting the surgery results. Since volume restriction is the primary rationale of the LSG, postoperative sleeve size and RGV are essential factors affecting the treatment results[8]. Obeidat et al.[14] reported that > 500mL RGV was associated with ≥ 50% %EWL. Since the same approach was performed in the operations, RGV was only affected by patient characteristics. In different studies, RGV was not a predictive factor of weight loss in long-term follow-up[10,15,16]. In our research, an RGV > 725mL was associated with a higher %EWL at the 12-month postoperative follow-up.

A study presented by Penna et al.[10] reported the RGV/SF as a more predictive factor in identifying patients at higher risk of postoperative complications and inadequate weight loss than RGV alone. The < 140 RGV/SF ratio was associated with increased intraoperative bleeding, prolonged ICU, and total length of stay. In comparison, an RGV/SF ratio > 212 positively affected BMI loss and %EWL at the 12-month postoperative follow-up. In our study, patients were grouped as low (RGV/SF, < 103.57) and high (RGV/SF, > 103.57) according to the RGV/SF ratio. No significant relationship was reported. In the subgroup analyses, a higher ratio was associated with decreased nausea-vomiting and increased hemorrhage. We also found that male and older patients were prone to have significantly increased RGV/SF ratio. Thus, the surgeon must be more alert regarding bleeding in male and elderly patients.

Weight regain is still a big problem in long term follow-up. Studies have shown that residual gastric volume after LSG tends to increase over time and is associated with weight regain. Although the extent of postoperative gastric volume expansion is significant regarding weight gain, patients undergoing standard LSG procedures have shown no difference in preserved gastric volume. This similarity has been demonstrated to have no impact on weight regain in these patients[17]. Weight regain after LSG may be associated with surgical technique, but the lack of consistent postoperative follow-up is also a crucial factor affecting long-term success. In a long-term follow-up meta-analysis by Clapp et al.[18], the obesity recurrence rate was 27.8% (95% CI: 22.8%, 32.7%) among patients followed for seven years or more. Initial BMI did not significantly impact recurrence (regression coefficient = -0.002, $p=0.86$). We may encounter up to %75.8 weight gain after sleeve gastrectomy in long term (6 years after surgery)[19,20]. Gastric capacity can increase late after sleeve gastrectomy and it is very important to measure objectively residual gastric volume before revisional surgeries[21]. It has been reported in the literature that the volume difference in the remnant stomach, which varies depending on the bougie diameter used, does not cause a significant difference in early weight loss outcomes[22]. Gastric dilatation is one of the factors that cause weight gain in the long term, even if it does not occur in the early period[23]. Notably, the need for revision surgery due to weight regain was reduced among patients with longer follow-up periods, highlighting the importance of consistent and extended follow-up in enhancing the long-term success of LSG. Although there was a statistically significant difference in the initial BMIs between groups in our study, the weight loss outcomes were unrelated to this initial difference. Technical modifications to prevent weight regain have been described in the literature, but long-term results are awaited[17]. In long-term success, it should be noted that sleeve gastrectomy (SG) plays a significant role through its restrictive effects and metabolic impacts. Numerous studies in the literature report that, over time, SG highlights metabolic effects by inducing changes in the gut microbiota and neurohormonal balance[24]. However, prospective experimental studies are needed to elucidate these changes fully[25].

Limitations

Since there was no SLL in our series, prospective studies with a higher sample size are needed to evaluate the significance of the RGV/SF ratio in predicting SLL.

Conclusion

This is the most extensive single-center series evaluating the predictive significance of the RGV/SF ratio on postoperative complications and weight loss. Our study showed that RGV/SF could be a predictive parameter in predicting the midterm results of the surgery.

Data availability

The datasets used and/or analyzed during the current study available from the corresponding author.

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Study conception and design: M.C.K.; Acquisition of data: C.B., M.C.K.; Analysis and interpretation of data: M.C.K., C.B., U.M.K., Critical revision of manuscript: M.C.K., A.U.M., C.S., E.A.; Approval of the final manuscript: All authors.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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