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A Representative Percentile Chart for Prediction of Weight Loss Trend after Sleeve Gastrectomy

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Keywords
Weight loss · Bariatric surgery · Sleeve gastrectomy · Obesity

Abstract
Introduction: It could be valuable for surgeons and patients to use one chart in different groups and evaluate weight loss during the post-surgery period. ***Methods:*** This retrospective study used the Iran National Obesity Surgery Database. Patients with clinically severe obesity aged 18–70 undergoing sleeve gastrectomy participated in this study. Body mass index (BMI) reduction and 5 other metrics measured over the study period were modeled using lambda-mu-sigma method. Our data were split into the train (70%) and test (30%) sets. ***Results:*** In this study, 1,258 patients (75% female) met the eligibility criteria to participate. Mean age and initial BMI were 36.87 ± 10.51 and 42.74 (40.37–46.36), respectively. Percentile charts for various metrics have been presented for the first 2 years after surgery. ***Conclusions:*** For sleeve surgery, all metrics are acceptable for clinical applications. Using the statistical view, BMI reduction is the most acceptable metric according to the lowest bias values and its variation between all the metrics.

Introduction

Obesity is a global pandemic associated with multiple serious medical problems [1]. Bariatric surgery (BS) is the only proven long-term effective treatment for obesity spreading globally [2]. Laparoscopic sleeve gastrectomy (LSG) is the most common procedure, accounting for 59.4% of the 228,000 annual bariatric procedures performed in the USA [3]. Compared to the alternative approaches like RYGB and other mal-absorptive surgery, the LSG is a technically convenient procedure with achievements in short-term weight loss (WL). These capabilities lead to more and more attention to this type of procedure, among other alternatives [4–6].

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The responses of all the patients to the surgery are not the same according to their variation in clinical, demographic, psychological, surgical, and genetic factors [7]. Therefore, most guidelines in the obesity surgery context recommend long-term follow-up at predefined post-operative intervals. One of the primary essential measures in these follow-ups is weight change.

The researchers routinely report weight change by several measurements. Although these measures evaluate the same phenomenon, there are few differences according to their definitions. A more convenient approach is to explore the whole distribution of measurements across time and individuals characteristics. For this purpose, the percentiles charts as the appropriate tools were proposed.

In this study, we aimed to explore and calculate the most common measurements and their percentile charts in the context of BS in a sample of patients who had undergone the LSG. In addition, we compare the available approaches to suggest the best way of using these tools.

Materials and Methods

Design and Participants

This retrospective study used the National Obesity Surgery Database that includes patients with severe obesity (body mass index [BMI] >35), from which 1,258 patients undergoing LSG participated through using the data from two surgeons of excellence. Data were retrieved from February 2008 to February 2020, to control the confounding effect of the COVID-19 pandemic [8] and contains the WL of the first 2 years post-surgery, the most influential period of weight changes.

There was a multidisciplinary support team for following-up the patients in post-operation and recorded the weight and date in the database during the routine visits which were set at 10 days, 1, 3, 6, 9, 12, 18, and 24 months but 2 extra months were also considered for the patients who delayed in their visits. We also contacted the patients who missed a visit and followed them up.

The patients who went under LSG as the primary surgery, aged between 18 and 70 years, were included in this study. The cases with an initial BMI <35 kg/m^2, mentally retarded, anastomotic stricture, leak, and pregnancy after surgery were excluded.

Metrics

According to our literature review, the 6 following metrics are more common in the context of BS [9].

- BMI (kg/m^2) = (weight)/(squared body length)
- BMI reduction = (weight at the surgery – last measured weight)/(squared body length)
- TWL = [(initial weight) – (post-op weight)]/[(initial weight)] 100]
- AWL = 100 × (BMI reduction)/(baseline BMI – 13)
- EWL = 100 × (weight at the surgery – last measured weight)/(weight at the surgery – ideal weight)
- EBMIL = 100 × (BMI reduction)/25

Body lengths and weight are declared as meter and kg in all these metrics, respectively. The ideal weight in EWL is computed according to individual body length and BMI equal to 25 as the ideal point.

Percentile Charts

The lambda-mu-sigma (LMS) method has been widely used for children's growth charts and shows the distribution of a positive measurement according to a covariate. Each part of the method's name indicates an aspect of the distribution of the outcome variable (skewness, median, and coefficient of variation, respectively, for *L*, *M*, and *S*). We extracted the 3, 10, 25, 40, 50, 60, 75, 90, and 97% percentile of all metrics from a standard normal distribution.

Validity and Generalizability

All metrics were introduced in this paper are potentially applicable for clinicians. On the other hand, some factors like gender, associated medical problems, and baseline BMI may affect the accuracy of the percentile chart. Therefore, we conduct a sensitivity analysis to explore which robust metric could be used in the broader situation.

At first, we split our data into train and test sets, respectively, with 70% and 30% of samples randomly chosen. The percentiles were estimated using the train data for all metrics. The test data were used to evaluate the metrics prediction ability when a new data point (which did not cooperate in the model building). We drew 1,000 bootstrap samples with replacement from the test data and calculated their percent lower than predefined percentiles. Concordance between the calculated percent and percentiles is an index for appropriate prediction. The difference between these values presented as bias and the variation of this criteria estimated using the bootstrap method. The appropriate estimator has the lowest bias and variance among other estimators.

Statistical Analysis

The baseline characteristics of the participants were summarized using mean and standard deviation for continuous variables, and frequency and proportion for categorical variables. The lowest bias and the related uncertainty interval (UI) were defined as selecting the best metrics. After applying the LMS method on test data, the bias and its UI for each percentile in all metrics were calculated using the Bootstrap method. This approach helped us to quantify the accuracy and validity of presented percentiles (shown in Fig. 1).

The type 1 error alpha was set at 0.05, so the confidence intervals were reported at level 95%. The statistical analysis and graph generations were conducted using *R* statistical software.

Results

Totally 1,258 patients met the eligibility criteria to enter the study, with the mean age being 36.87 years. The majority of patients were females. The prevalence of type 2 diabetes mellitus and hypothyroidism among samples were 7.93% and 16.45%, respectively (Table 1).

In addition, we compared the baseline characteristics and final situation of patients by baseline BMI categories

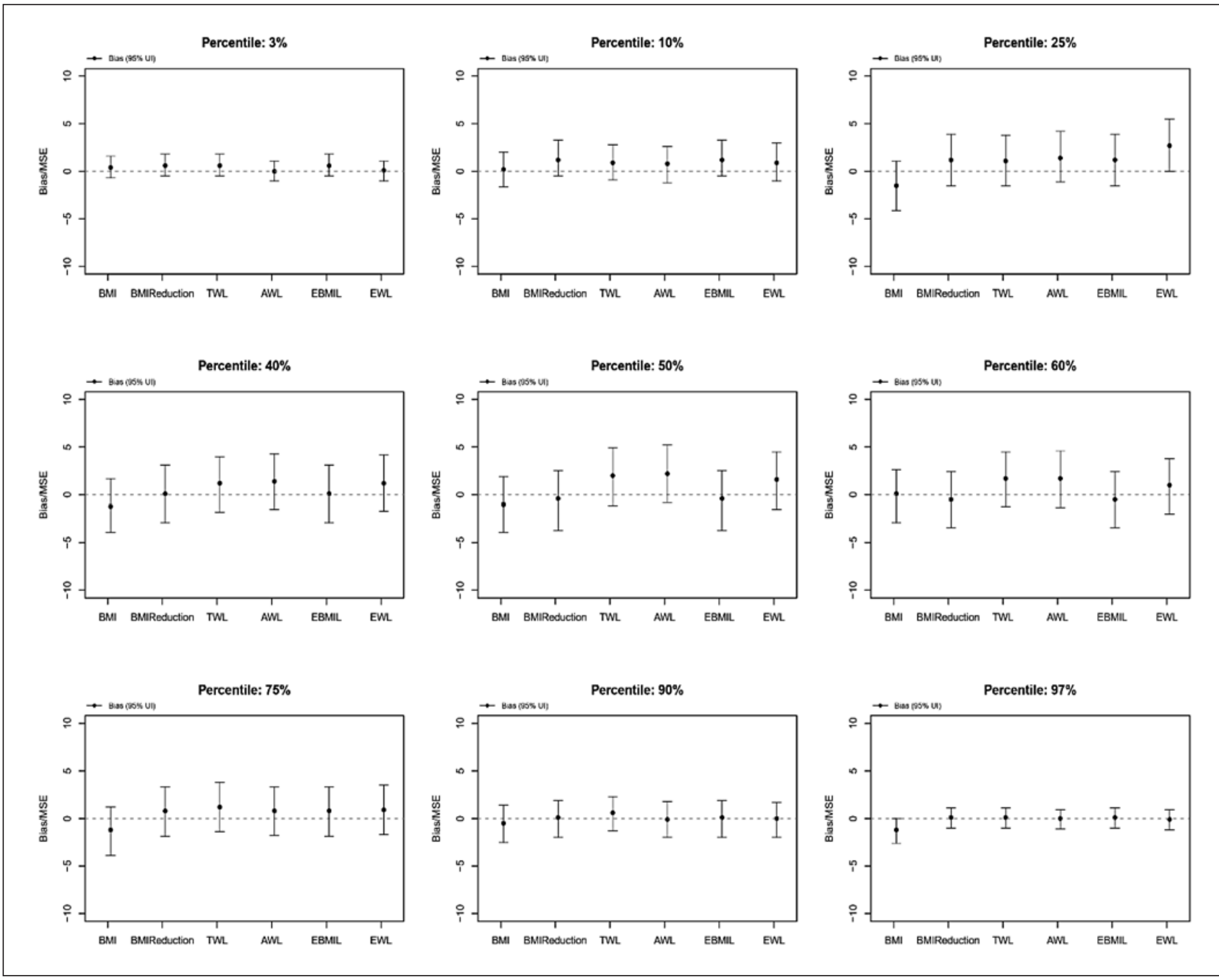

Fig. 1. Evaluation of metrics according to the bias and 95% uncertainty interval over different percentiles.

(35–40, 45–50, and 50+) in Table 1. According to this table, most patients (857 patients equal to 68.12%) belong to the BMI category 45–50 in the baseline comparison. The gender distribution (p value <0.01), the prevalence of hypothyroidism (p value = 0.048), and diabetes (p value = 0.001) were different among baseline BMI categories. On the other hand, patients with severe obesity tended to adhere to follow-up visits. In this manner, an almost linear trend 3, 5, and 6 for the median number of visits and 2.7, 3.1, and 3.54 for follow-up months were seen across the groups.

Although some metrics were normally distributed, we used median and interquartile range to describe them to comparability (Table 1). Among all metrics, AWL is more robust to the difference in baseline BMI, and there is no statistical difference in AWL in the last follow-up between the groups (p value = 0.89).

The evaluation of metrics according to the bias and UI over different percentiles is shown in Figure 1. This figure includes bias and its 95% UI calculated by the bootstrap method.

The positive bias means there is a chance that our percentile chart could overestimate the true percentile. In the same regard, a negative bias, as we can see for BMI metric in percentiles 25%, 40%, 50%, 75%, 90%, and 97%, indicates underestimates of exact percentile. All the absolute bias values are less than 5, which leads our percentile charts for all metrics in the worse cases may misclassify a

Table 1. Sociodemographic characteristics of the sample.

Variable	Baseline BMI, kg/m^2			Total	*p* value
	35–40	40–50	50+		
Subjects, *N* (%)	259 (20.59)	857 (68.12)	142 (11.29)	1,258	
Female, *n* (%)	220 (84.94)	639 (74.56)	93 (65.49)	952 (75.68)	<0.001
Age, mean±SD, years	36.70±10.11	36.79±10.32	37.64±12.26	36.87±10.51	0.64
Baseline BMI, median (IQR)	37.81 (36.62–38.95)	43.28 (41.51–45.28)	53.25 (51.60–58.01)	42.74 (40.37–46.36)	–
Hypothyroidism, *n* (%)	49 (18.92)	135 (15.75)	23 (16.20)	2 07 (16.45)	0.048
Diabetes, *n* (%)	27 (10.42)	48 (5.60)	18 (12.68)	93 (7.39)	0.001
Visits, median (IQR), *n*	3 (2–6)	5 (3–7)	6 (4–8)	5 (3–7)	<0.001
Follow-up time, median (IQR), months	2.7 (1–6.83)	3.1 (1–8.4)	3.54 (1.03–9.6)	3.1 (1–8.4)	0.02
BMI in last follow-up, median (IQR), kg/m^2	31.28 (27.58–34.04)	35.74 (30.94–39–12)	42.96 (36.57–48–43)	34.87 (30.29–39–04)	<0.001
BMI reduction in last follow-up, median (IQR), kg/m^2	6.05 (3.96–9.77)	8.02 (4.43–12.74)	11.45 (5.76–17.56)	7.89 (4.39–12.39)	<0.001
%AWL in last follow-up, median (IQR), kg	24.71 (15.69–40.50)	26.38 (14.09–42.04)	28.02 (12.97–42.69)	25.91 (14.61–41.64)	0.89
%EWL in last follow-up, median (IQR), kg	49.35 (30.06–79.51)	42.80 (23.57–69.08)	38.81 (18.66–58.78)	42.87 (24.12–69.99)	<0.001

kg, kilogram; m, meter; *N*, number; SD, standard deviation; IQR, interquartile range; BMI, body mass index; EWL, excess weight loss; AWL, alterable weight loss.

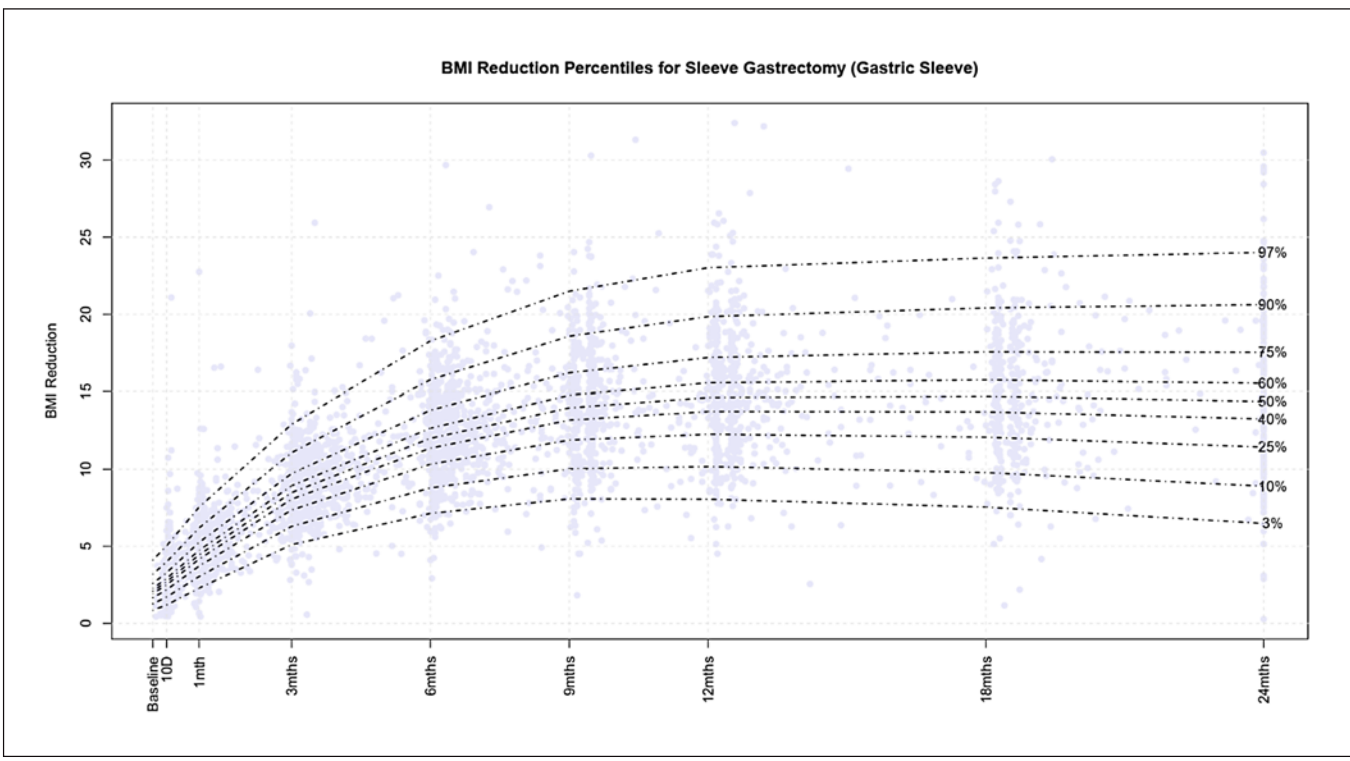

Fig. 2. Body mass index reduction percentiles for sleeve gastrectomy.

patient into a percentile differ +5% or −5% from the true one. This scenario is highly extreme and never would happen. As a real example, the bias for BMI reduction in percentile 50% (the percentile with the highest values of bias) is equal to −0.2. This value means a patient who belongs to the true percentile 50% has a chance to be misclassified in percentile 49.8%.

On the other hand, the 50% and 40% percentiles for 6 months after surgery are 12 and 11.36 (kg/m^2 BMI reduction), respectively. Therefore, the bias −0.2 is almost equal to an underestimate of 0.13 in BMI reduction. Using the same approach, all the metrics are acceptable for clinical applications. Using the statistical view, BMI reduction is the most acceptable metric according to the lowest bias values and narrow UI between all the metrics.

Figure 2 depicts the various percentiles of BMI reduction in the predefined patient visits. According to this figure, the BMI reduction rate is related to the first 3 months after surgery. The BMI reduction continued to the first year, but the rate of change was reduced. The BMI of patients after 1 year seems to be stable for most of the patients (upper than percentile 10%). Almost 3% of patients start to weight regain in 12 months and 24 months after surgery. The percentile of other metrics is available in the online supplementary (for all online suppl. material, see www.karger.com/doi/10.1159/000527721). It needs to be mentioned that TWL and EWL are similar except to a constant. Therefore, their stochastic function is the same, and clinicians could equally use it as they prefer.

Discussion

We present the first WL percentile chart for LSG during the post-surgery period, accounting for all observed and nonobserved background variables. It could be more valuable and applicable for surgeons and patients to use only single chart for all the patients with different characteristics. These percentiles are especially useful for early detection of WL failure and intervening in nutritional and physical activity approach.

There are several alternatives for selecting the most appropriate metric when the researchers wanted to draw percentile charts for WL after BS. These choices vary from crude BMI [10] to more complicated ones like %EWL [11, 12], excess BMI and total WL [13], and %AWL [14]. Among these studies, only van de Laar et al. [15] explore a wider range of metrics and conclude the %AWL is the best choice for drawing percentile charts among them. Our research continued the work of others, evaluating all post-operative metrics, including BMI, BMI reduction, %TWL, %AWL, %EWL, and %EBMIL. Finally, a significant difference was not observed between metrics in their statistical functionality and the users understanding from the metric concept could be better criteria for choosing the metric.

According to baseline characteristics, a study on the Bariatric Outcomes Longitudinal Database showed the %TWL as metric independence from the patient's initial BMI [16]. In addition, van de Laar et al. [14] suggest the %AWL as the most robust metric for the initial BMI variation. There are plenty of covariates as BMI or WL determinants after surgery. Controlling or stratification of the percentile charts based on all these factors is not applicable, and the results could lose their accuracy in terms of data scarcity. Therefore, we used a novel approach to put this accuracy loss into the model, and interestingly, the results showed the bias is ignorable. In this manner, we achieve a valid percentile chart for all the metrics regardless of baseline characteristics.

One of the most important aspects of developing a percentile chart is the statistical methodology of its development. In a statistical manner, the best approach is the one that balances the bias and variance trade-off. The more complex methods decrease the bias and increase the variation of estimation. On contrary, the simplest ones put more emphasis on the variance. In the context of percentile charts, various statistical methods have been used to evaluate post-operative WL and the related metrics [17].

Dallal et al. [11] developed multivariable mixed models in the longitudinal analysis of post-operative WL outcomes. Applying this chart in clinics is difficult, and a close link between clinicians and statisticians is obligatory. Non-generalizability of multivariable mixed models results could be mentioned as one of the other limitations. Mor et al. [12] carried out another study to construct nomograms instead of percentile chart to evaluate WL for each follow-up visit. Another Spanish cohort study developed a percentiles chart without using any smoothing model or considering initial BMI, one of the most important factors in post-operative WL [6]. An Asian cohort study offered percentile charts to follow WL after BS using quantile regression models [13]. This could cause heterogeneity among participants or samples. In line with our project, Van de Laar et al. [18] have built bariatric WL charts with LMS method to examine patient WL without validation for baseline characteristics.

One of the missed critical components in the statistical analysis of research in this context is the misspecification of assumptions. Due to BMI and related measures in this context rarely following normal distribution, the LMS method can address this issue by finding the best transformation to detect normal distribution. This method is easy to interpret and generalizable for other settings, and researchers interested in the percentile debate have been using this method in recent years [19].

The results of our study demonstrated that BMI, BMI reduction, and ALW% are the three metrics more robust to the difference in baseline characteristics. Meanwhile, BMI reduction is the most acceptable metric according to the lowest bias and narrowest UI by 1,000 repetition using test and train approach. In other words, the BMI reduction metric would be represented as a better post-operative WL independent from baseline variables.

Our findings suggest that BMI reduction and EBMIL had similar stochastic function in the WL percentile chart and BMI reduction could be more easily interpretable by patients in clinical settings. Indeed, AWL percentile is more robust to the differences in baseline BMI, and there is no statistical difference in AWL in the last follow-up among the patients.

Considering the nature of our data, some possible limitations were unavoidable like choosing the type of LSG for participants which was not randomly assigned, but dependent on the characteristics of them, such as having associated medical problems (like T2DM), the amount of preoperative obesity, eating habits, etc. [20, 21]. Although we explored the internal validity of proposed percentile charts using the test and train approach, an exciting extension could be exploring the external validity of our findings using other similar databases.

Conclusion

The primary output of this study is the validated percentile charts for various common metrics regardless of baseline characteristics of patients. In addition, our findings highlighted that all mentioned metrics for LSG are acceptable and applicable for clinical applications.

Statement of Ethics

The research adhered to fundamentals of Declaration of Helsinki. The written informed consent to participate in the study was obtained from participant. Ethical Committee of the Iran University of Medical Sciences approved the protocol for this study (Number: IUMS REC.1397.464).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Somayeh Mokhber: conceptualization, methodology, formal analysis, and writing original draft. Ali Sheidaei: conceptualization, methodology, and formal analysis. Farnaz Farsi: conceptualization and assistance in writing original draft. Seyed Amin Setarehdan: conceptualization, acquisition of data, methodology, and formal analysis. Mohammad Ali Mansournia: conceptualization, supervision, review and editing. Masoud Solaymani-Dodaran: conceptualization, formal analysis, supervision, review and editing. Ali Kabir: conceptualization, formal analysis, supervision, review and editing. Mohammad Reza Abdolhosseini: conceptualization, acquisition of data, and supervision. Abdolreza Pazouki: conceptualization, acquisition of data, and supervision.

Data Availability Statement

The data that support the findings of this study are not publicly available due to patient confidentiality rules in Minimally Invasive Surgery Research Center but are available either from the corresponding author (msdodran@gmail.com) or Dr Somayeh Mokhber, the responsible officer at the Minimally Invasive Surgery Research Center upon reasonable requests, e.g., use of data by researchers in academic institutions.

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