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ORIGINAL CONTRIBUTIONS

Usefulness of Baltasar's expected body mass index as an indicator of bariatric weight loss surgery

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Abstract
Introduction Determining the best indicator to report weight loss takes on special relevance following bariatric surgery. Our objective is to apply a method proposed by Baltasar et al. to express weight loss results following bariatric surgery.
Materials and methods Anthropometric data were collected from 265 patients who had undergone Sleeve gastrectomy (SG, $n = 172$) and Roux-en-Y gastric bypass (RYGBP, $n = 93$) with a 2-year follow-up period. Initial BMI was calculated as well as BMI 2 years after, percentage of excess BMI loss (PEBMIL), expected BMI (EBMI), and corrected PEBMIL.
Results In SG group, average BMI 2 years after surgery fell within a 95 % CI of expected BMI, with an average BMI of 31.58 ± 4.05 kg/m^2 in 35–45 BMI group, an average BMI of 33.62 ± 4.96 kg/m^2 in 45–55 BMI group, and an average BMI of 37.40 ± 5.93 kg/m^2 in 55–65 BMI group. In RYGBP group, average BMI 2 years after the surgery was below than average expected BMI (28.76 ± 3.20 kg/m^2 in 35–45 BMI group and 29.71 ± 3.30 kg/m^2 in 45–55 BMI group). Results are considered excellent for the group with an initial BMI of above 45 kg/m^2.
Conclusions EBMI is a good weight loss indicator, mainly when 95 % CI is taken into account. EBMI is consistent with the results obtained 2 years after surgery in our patients who underwent SG and RYGBP. Corrected PEBMIL is a good indicator for expressing the percentage of BMI loss and offers more realistic values than conventional formula with a cut-off point of 25 points.

Keywords Obesity · Bariatric surgery · Weight loss · Body mass index · Roux-en-Y gastric bypass · Sleeve gastrectomy

Introduction

In recent years, a certain amount of controversy has arisen over how to evaluate weight loss in the context of bariatric

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surgery, specifically in terms of selecting the most appropriate indicator for expressing the results of such procedures. It has been difficult to define the criteria for success in terms of weight loss and even more difficult to provide our patients with realistic and achievable expectations [1]. The percentage of excess weight loss (%EWL) calculates the patient's ideal weight, usually taken from the tables produced by the Metropolitan Life Insurance Company of New York [2] in 1983 and based on American population or from the weight corresponding to a BMI 25, as proposed by Deitel et al. [3]. Up to now, most authors have used indicators such as the %EWL or the percentage of excess BMI loss (PEBMIL). In Spain, the tables published in 1982 by Alastrué et al. [4] for the Catalan population have also been used; however, the age of these references makes them less than fully representative. Setting the ultimate objective of the surgery as reaching one's ideal weight makes success difficult to achieve in most cases. On the other hand, PEBMIL uses a BMI of 25 kg/m^2 as a cut-off point [5], which is also difficult to achieve, especially for patients with an initial BMI of more than 50 kg/m^2 [6]. To evaluate weight loss using these indicators, Baltasar classifies results according to the following criteria: excellent when the result is above 65 %, good when the result is between 50 and 65 %, and poor when it is less than 50 % in terms of PEBMIL [7]

Absolute weight loss expressed in kilograms is another indicator that has been used, although because this figure is influenced by the patient's initial weight, it can lead to confusion when attempting to compare results with those obtained by other researchers. For this reason, the option of expressing results in relative terms such as %EWL or PEBMIL is often selected.

The standards for weight are currently changing, with a progressive, alarming increase in the prevalence in overweight and obesity all over the world [8]. This implies the need to review the indicators used for reporting weight changes in any treatment context related to obesity and overweight.

In relation to bariatric surgery, Baltasar et al. have proposed calculating a new indicator called expected BMI [9], which would be the BMI that patients could be expected to achieve taking their initial BMI into account. This indicator proposes an individualized BMI that should be achievable as of 2 years after surgery. Considering that each surgical technique has a specific indication and that the expected results are different, Baltasar et al. later proposed using a different formula for each surgical technique [10].

Our objective is to apply this indicator to express weight loss results, so that patients opting for bariatric surgery can be given a more realistic expectation. At this point, we have evaluated whether our actual results fit with the theoretical predictions of the formula.

Materials and methods

We performed a retrospective review of the clinical histories of 265 patients who underwent bariatric surgery during the period between 2006 and 2012, with two full years of follow-up. Study methods were in compliance with the Declaration of Helsinki [11]. Ethics Committee of the Sant Joan University Hospital of Reus approved the study. The patients signed study-specific informed consent form. Anthropometric data were recorded both prior to surgery and 24 months after the procedure for patients who received Roux-en-Y gastric bypass (RYGBP, $n=93$) or sleeve gastrectomy (SG, $n=172$). Initial BMI and the patients' BMI at 24 months after surgery were calculated (BMI = kg/m^2). These figures were used to calculate the number of BMI points lost at 24 months after surgery. The PEBMIL at 24 months after surgery was also calculated (PEBMIL = (initial BMI − final BMI)/(initial BMI − 25) × 100).

The formulas proposed by Baltasar et al. were also used to calculate the average and 95 % confidence interval (95 % CI) for the expected BMI (EBMI) for each surgical technique and corrected PEBMIL:

$$\text{Sleeve gastrectomy EBMI} = \text{initial BMI} \times 0.43 + 10.88$$
$$\text{Roux-en-Y gastrojejunal bypass EBMI} = \text{initial BMI} \times 0.43 + 10.23$$

The corrected PEBMIL was calculated by replacing the BMI cut-off point of 25 points with the EBMI obtained using the formulas above. The interpretation of the results is based on the idea that all of the patients should get as close as possible to 100 % of this figure and that those who exceed 100 % should be considered as having achieved excellent results.

$$\text{corrected PEBMIL} = [(\text{initial BMI–final BMI}) / (\text{initial BMI–EBMI for each technique})] \times 100$$

The results were stratified into several groups based upon initial BMI: 35–45, 45–55, 55–65 kg/m^2 (SG) and 35–45, 45–55 kg/m^2 (RYGBP). The results are represented as mean values and one standard deviation. To evaluate the relationship between initial BMI and BMI at 2 years, Spearman's correlation coefficient was used. For the comparison of means between techniques, we used the Student t test. Statistical significance was considered as $p<0.05$. Statistical analysis was performed using SPSS statistical software v.22.0 (SPSS Inc., Chicago, IL, USA).

Results

The data for 265 patients were analyzed (74.4 % female, 25.6 % male), with an average age of 46.98 ± 11.27 years; an average weight of 126.52 ± 22.68 kg; and an average BMI of 47.78 ± 7.51 kg/m^2. Table 1 shows the baseline

Table 1 Baseline characteristics of the sample

	Full sample $n=265$	SG $n=172$	RYGBP $n=93$
Men (*n*/%)	68/25.6	51/29.7	17/18.1
Women (*n*/%)	198/74.4	121/70.3	77/81.9
Age (years)	46.98 ± 11.27	48.70 ± 11.43	43.94 ± 10.30
Weight (kg)	126.52 ± 22.68	131.02 ± 24.99	118.27 ± 14.53
BMI (kg/m^2)	47.78 ± 7.51	49.33 ± 8.38	44.93 ± 4.33

characteristics for the entire sample, according to the type of surgery.

Table 2 shows the results obtained for the various indicators in the group of patients that underwent SG surgery, stratified into three BMI groups (35–45, 45–55, and 55–65 kg/m^2).

The SG patient groups with an initial BMI of 45–55 or 55–65 kg/m^2 obtained the best results according to the corrected PEBMIL calculation. Patients with a higher initial BMI achieved results the closest to the expected value of 100 %. The average PEBMIL using the corrected formula was 84.93 % (range 70.48–99.39) for the entire SG group.

Figure 1 shows the relationship between the initial BMI and the BMI 2 years after surgery for the SG group. There is a significant positive statistical correlation between the initial BMI and the BMI 2 years after surgery ($r=0.581$; $p=0.000$).

Table 3 shows the results obtained for the various indicators in the group of patients that underwent RYGBP surgery, stratified into two BMI groups (35–45 and 45–55 kg/m^2) using a BMI of 45 kg/m^2 as a cut-off point.

In the RYGBP group, the patients with an initial BMI of over 45 kg/m^2 achieved the best results when the corrected PEBMIL was calculated and even exceeded the expected value by 7 %. The average using the corrected formula was 99.11 % (range 94.41–103.82) for the entire RYGBP group.

Figure 2 shows the relationship between the initial BMI and the BMI 2 years after surgery for the RYGBP group. There is a significant positive statistical correlation between the initial BMI and the BMI 2 years after surgery ($r=0.384$; $p=0.000$).

Table 4 shows the results of comparing both techniques adjusted by a BMI between 45 and 55 kg/m^2 (most numerous of our data collection). In terms of PEBMIL (25 and expected) and BMI at 2 years, the results are better in RYGBP group ($p<0.05$)

Discussion

In the field of bariatric surgery, although great importance has been placed on the appearance of new techniques and the refinement of others in recent years, the same concerns persist with regard to the amount of weight loss our patients should achieve. Up until now, PEBMIL and %EWL have been used as indicators to express patients' weight loss results, but as the patients and surgical techniques evolve, the indicators should also be adjusted and individualized, and most importantly, the starting point for each patient should be taken into account. We need to adapt to the times and think about the patients in a more individualized manner whenever possible, offering realistic expectations with the primary objective of improving their quality of life.

As a result of the uncertainty regarding weight loss following surgery and the best way to express it, in recent years, Baltasar et al. [10] as well as other researchers such as Van de Laar et al. [12] have presented the possibility of using other indicators that are more relevant to the realities of today's world.

As shown here, expected BMI as proposed by Baltasar et al. is a good weight loss indicator in bariatric surgery, particularly when 95 % CI is taken into account. It is consistent with the results obtained 2 years after surgery in our sample of patients who underwent SG and RYGBP procedures. The corrected PEBMIL is a good indicator for expressing the

Table 2 Differences between BMI lost, expected BMI, and PEBMIL in patients who have undergone Sleeve gastrectomy

Initial BMI (kg/m^2)	35–45 $n=48$	45–55 $n=87$	55–65 $n=25$	All $n=172$
Expected BMI (kg/m^2)				
Lower limit[a]	26.46 ± 0.85	29.56 ± 1.14	33.60 ± 1.30	27.45 ± 0.28
Average	28.96 ± 0.87	32.13 ± 1.17	36.27 ± 1.33	29.47 ± 0.18
Upper limit[a]	31.89 ± 0.91	35.21 ± 1.22	39.54 ± 1.39	35.11 ± 0.30
BMI at 2 years (kg/m^2)	31.58 ± 4.05	33.62 ± 4.96	37.40 ± 5.93	34.31 ± 0.50
BMI lost (kg/m^2)	10.51 ± 3.97	16.00 ± 5.53	20.95 ± 5.06	14.89 ± 0.57
PEBMIL BMI = 25 (%)	61.83 ± 22.60	64.74 ± 21.27	63.33 ± 19.97	59.98 ± 3.28
Corrected PEBMIL (%)	80.21 ± 29.12	91.46 ± 29.98	94.18 ± 24.70	84.93 ± 7.31

BMI body mass index (kg/m^2), *PEBMIL* percentage of excess BMI loss (%)

[a] Corresponding to the 95 % CI for the formula

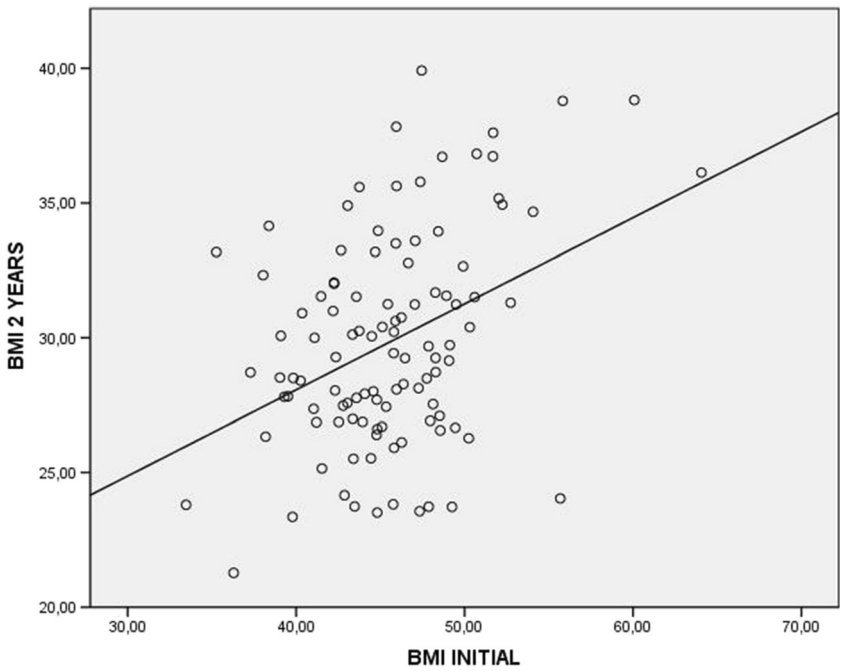

Fig. 1 Relationship between initial BMI and BMI 2 years after surgery in SG patients ($n = 172$)

percentage of BMI loss, and it offers more realistic values than the conventional formula with its cut-off point of 25 points.

The SG technique arose as the initial stage of biliopancreatic diversion (BPD), which is the best option in terms of weight loss, although over the years, it has gained importance in and of itself [13]. We consider SG as one of the technique of choice as a first step of BPD-DS for super obese patients as well as for those to be considered as high-risk [14, 15].

In our case, because of the characteristics of our sample, the patients who underwent SG were divided into three BMI groups and not all of them achieved 100 % of the corrected PEBMIL. This can be explained by the fact that at our facility, this surgery is used in many cases as a first-time surgery for patients with a very high BMI or with high surgical risk. Nevertheless, the results ranged from 80 to 94 %, which are values close to the established target and better than those achieved when the conventional formula is applied. This surgical technique is perhaps the one that most benefits from the application of this indicator, as patients with a BMI of over 50 kg/m^2 face the most difficulty in achieving a BMI of 25 kg/m^2, which is the cut-off point for the conventional formula. This explains the suitability of using the expected BMI based on the surgical technique as a weight loss indicator; it is an individualized value that is attainable by most patients.

Table 3 Differences between BMI lost, expected BMI, and PEBMIL in patients who have undergone Roux-en-Y gastric bypass

Initial BMI (kg/m^2)	35–45 $n = 48$	45–55 $n = 45$	All $n = 93$
Expected BMI (kg/m^2)			
Lower limit[a]	26.06 ± 1.03	28.89 ± 1.05	27.64 ± 0.19
Average	28.20 ± 1.05	31.10 ± 1.07	29.81 ± 0.20
Upper limit[a]	30.76 ± 1.10	33.79 ± 1.12	32.44 ± 0.21
BMI at 2 years (kg/m^2)	28.76 ± 3.20	29.71 ± 3.30	29.84 ± 0.34
BMI lost (kg/m^2)	13.05 ± 4.10	18.78 ± 3.71	15.70 ± 0.48
PEBMIL BMI = 25 (%)	76.99 ± 21.40	80.01 ± 13.26	76.77 ± 1.86
Corrected PEBMIL (%)	94.95 ± 26.60	107.74 ± 18.04	99.11 ± 2.37

BMI body mass index (kg/m^2), *PEBMIL* percentage of excess BMI loss (%)

[a] Corresponding to the 95 % CI for the formula

In their systematic review on weight loss following SG, Fischer et al. reported a %EWL of 64.5 % (range 46.1–75.0) at 2 years after surgery [11]. Their study also showed that SG is equivalent to RYGBP in terms of %EWL at 24 months after surgery. However, when adjusting our data to BMI between 45 and 55 kg/m^2, the RYGBP offers better results at 2 years significantly. In the case of SG, further research is needed into the results obtained and how to improve them in the future, as our objective is to obtain 100 % when using the corrected PEBMIL formula.

In the case of patients who received RYGBP surgery, we divided our sample into two initial BMI groups. In the first group, the results were very good, and in the second, they exceeded 100 % the corrected PEBMIL was calculated. Again, these results are better than those obtained when we used the conventional formula, and 2 years after surgery, the patients had achieved an average value below the expected BMI.

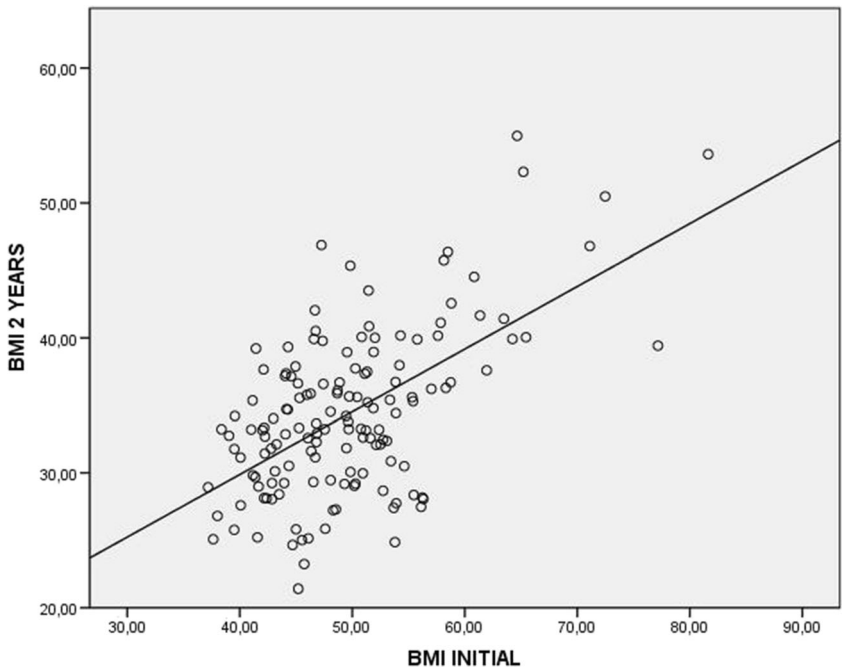

Fig. 2 Relationship between initial BMI and BMI 2 years after surgery in GBP patients ($n = 93$)

There are other proposals for evaluating weight loss after bariatric surgery, such as that published by Van de Laar et al., who propose calculating the percentage of total weight loss (%TWL) using the following formula: 100 % × BMI loss/initial BMI [12, 16, 17]. They have also proposed calculating the percentage of alterable weight loss (%AWL) using the formula: 100 % × BMI loss/(initial BMI − 13) [18]. Later, Van de Laar et al. created some percentile charts for %TWL and %AWL derived from a large sample of patients who underwent RYGBP surgery [19]. Sczepaniak et al. also reviewed weight loss indicators in bariatric surgery and demonstrated that %TWL has a lower coefficient of variation than %EWL or PEBMIL [20]. These indicators may prove to be very practical as a way of expressing the effectiveness of surgical intervention. %TWL is helpful to compare publications and avoid variability due to initial BMI. Absolute terms to express weight loss are preferable in these cases. EBMI may be very useful in daily clinical practice, or to give a realistic expectation regarding the approximate weight of the patient. With this, we express weight loss with two distinct and non-exclusive orientations. In addition, BMI brings an important variable such as height's patient, which is not taken into account in TWL formulas. We must assume that our patients seldom **R1** lose 100 % of their excess weight. On this basis, the EBMI is offered as a useful alternative to answer realistically many questions from our patients.

Table 4 Differences between patients who have undergone Roux-en-Y gastric bypass and sleeve gastrectomy, adjusted by BMI (45–55 kg/m^2)

	SG $n = 87$	RYGBP $n = 45$	p value
BMI at 2 years (kg/m^2)	33.62 ± 4.96	29.71 ± 3.30	0.000
BMI lost (kg/m^2)	16.00 ± 5.53	18.78 ± 3.71	0.070
PEBMIL BMI = 25 (%)	64.74 ± 21.27	80.01 ± 13.26	0.001
Corrected PEBMIL (%)	91.46 ± 29.98	107.74 ± 18.04	0.000

BMI body mass index (kg/m^2), *PEBMIL* percentage of excess BMI loss (%)

*corresponding to the 95 % CI for the formula

Conclusion Calculation of EBMI proposed by Baltasar et al. is a very useful tool in daily clinical practice and it offers patient expectations that are realistic and achievable within a specific period of time, taking into account both absolute value and 95 % CI. Corrected PEBMIL can also be a very useful tool, as a result derived by the EBMI individualized technical, although it is necessary creating a scale for results interpretation.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Ethical Approval All procedures are in accordance with the ethical standards of our institution's committee research (Ethics Committee of Sant Joan University Hospital) and with the 1964 Helsinki declaration as ethical standards.

Informed Consent Informed consent has been obtained from all individual participants included in our collection.

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