CHANGES OF BODY COMPOSITION IN PATIENTS WITH BMI 23–50 AFTER TAILORED ONE ANASTOMOSIS GASTRIC BYPASS (BAGUA): INFLUENCE OF DIABETES AND METABOLIC SYNDROME

M. Garciacaballero & A. Reyes-Ortiz & M. García & J. M. Martínez-Moreno & J. A. Toval & A. García & A. Mínguez & D. Osorio & J. M. Mata & F. Miralles

Abstract

Background: The use of bariatric surgery to treat diabetes mellitus (DM) requires procedures developed for morbid obese in patients with normal and over-weight. Therefore, we started tailoring one anastomosis gastric bypass (BAGUA) adapted to each patient. This study analyzes chang- es in body composition (BC) of patients with BMI 23–50 after BAGUA as well as influence of DM and MS.

Methods: We studied 79 (37 diabetic and 42 non-diabetic) patients (BMI 23–50) who completed all evaluation appoint- ment (preoperative, 10 days, 1, 3, 6, and 12 months) after tailored BAGUA for obesity, diabetes, or diabesity. Patients were classified according to BMI (23–29, 30–34, 35–50) and bearing or not diabetes. Variables are components of BC as well as DM and MS.

Results: Preoperatively, mean values of weight varied 37 kg (78–115 kg), muscle mass (MM) 8 kg (54–62 kg), while fat mass (FM) 30 kg (22–53 kg). Basal metabolism (BM) was higher in diabetic. After surgery, percentage (%) of excess weight loss (%EWL) ranged from 76 % (BMI 35–50) to 128 % (BMI 23–29), FM 56 % (BMI 23–29) to 65 % (BMI 35–50), without differences bearing DM. MM 12 % (non- diabetics BMI 30–34) to 17 % (diabetics BMI 35–50) and visceral fat (VF) 50 % (diabetics BMI 30–34) to 56 % (non- diabetics BMI 35–50).

Conclusions: After tailored BAGUA, MM maintains steady while FM is highly reduced and variable. BM is reduced in all groups. Diabetics lose less weight and VF but more MM than non-diabetic patients. Preoperative presence of MS influences the changes in BC.

Keywords: Body composition . Diabetes mellitus . Metabolic syndrome . Gastric bypass . BMI

Introduction

Surgical outcomes of bariatric surgery are usually measured by percentage (%) of excess weight loss (%EWL), BMI, and resolution of comorbidities. However, there are few studies [1–4] of the changes in body composition (BC) [5–8]. BC consists of fat-free mass (FFM) and fat mass (FM). FFM includes water, muscle, bone, connective tissue, and viscera [9] and contains 70 % water while FM has less than 25 %. Hydration state could affect the values of FFM in BC assessments [5].

The FFM is determinant of basal metabolism (BM) [10, 11] and core body temperature [12], preserving the integrity of the skeleton and osteoporosis prevention [13]. BM accounts for 60–70

% of total energy expenditure that include also post- prandial energy (10 %) and physical activity (20–30 %) [14].

The maintenance of skeletal muscle contributes to improve the quality of life by maintaining the functional capacity with age [15, 16]. Humans lose 3 kg of muscle mass (MM) per decade, which is directly related to increased risk of bone fractures [15, 17]. The optimal amount of MM loss in obese has a safe range between 20 and 30 % [18]. Moreover, rapid weight loss of about 0.3 kg/day over a period of 2 to 8 months produces fatal cardiac arrhythmias [19]. Therefore, weight loss procedures must be able to lose FM while preserving MM, because it helps in regulation of BM [10].

BC have been implemented only recently in obesity surgery [1] by a minority of bariatric groups. There is controversy about the appropriateness of the methods used [2].

The metabolic effects of bariatric surgery no longer matter baseline BMI. The effect of type 2 diabetes mellitus (T2DM) on the BC has not been studied until know. One study [20] revealed that greater visceral to subcutaneous fat ratio is considered as a predictive parameter of poor outcome following diabetic surgery. Another [21] mentioned that bariatric surgery does not produce excessive weight loss in patients with BMI 25–35, but BC was not evaluated. Our group has published BC data in diabetic patients with BMI 24–34 after surgery performing tailored BAGUA [22, 23]. Tailoring the surgery to preoperative BMI has given us the opportunity to operate wide BMI range for diabetes, obesity, or diabesity.

The aim of this study is to analyze the relationship among BC changes in different BMI and different degree of malabsorption provoked through tailored BAGUA and the influence of metabolic disorders.

Patients and Methods

Patients

We analyzed 79 patients (37 diabetic and 42 non-diabetic) with BMI 23 to 50, mean age 49 (range from 17 to 81) who had undergone tailored BAGUA and completed all evaluation appointment (preoperative, 10 days, 1, 3, 6, and 12 months), the first postoperative year.

Preoperative Evaluation

A preoperative study was conducted following the Clinical Practice Guideline of the European Association for Endoscopic Surgery [24]. We group the patients according to BMI and the presence of diabetes (Table 1).

Body Composition Analysis

BC analysis was performed using a single frequency impedance analyzer (TANITA® brand, model BC- 420MA). This equipment provides estimated values for FM, MM, bone mass, visceral fat (VF), BM, and total water (TBW) calculated by passing an alternating current through the patient to measure the water con- tent, where approximately 73 % corresponds to MM.

FM is obtained by subtracting the weight of FFM to the TBW. Other components are calculated using validated mathematical formula [25]. %EWL was calculated subtracting the ideal weight given by the impedance analyzer to the preoperative weight of the patient.

All our patients were evaluated in the morning after breakfast, preoperatively, and the next evaluation appointment followed up after surgery.

Surgical Procedure

All patients eat only liquid diet during 5 (BMI 23–34) to 7 days (BMI 35–50) depending on preoperative BMI, received antibiotic and antithrombotic prophylaxis.

Tailored BAGUA [22, 23] consisted in the construction of a gastric pouch from the gastroesophageal junction to the lower level of the cisura angularis. The stapler line of the gastric pouch was fixed approximately 12 cm to the intestinal loop (first layer of anti-reflux mechanism), and it was anastomosed in a laterolateral position to the mesenteric border of a small bowel loop 100 cm (BMI 23–29), 120 cm (BMI 30–32), 150 cm (BMI 33–34), 200 cm (BMI 35–40), 250 cm (BMI 40–45), and 280 cm (BMI 45–50) distal to the Treitz ligament. We perform the anastomosis over this first layer which creates a barrier that separates both cavities: stomach and intestine, avoiding the entry of biliopancreatic secretion to the stomach and adding restriction to the stomach empty. The anti-reflux mechanism is completed fixing the afferent loop to the gastric remnant and the efferent loop to the antrum. As it can be appreciated after the description, this procedure is completely different from mini GB. The size of the gastric pouch depends on the BMI of the patient. In BMI 23–32, we performed a floppy 36 French bougie pouch, while in BMI >33, a narrow 36 French bougie one's is per- formed. We left a drainage during 48 h of hospital stay.

Table 1: Patient's characteristics and distribution by BMI

BMI range groups	Number of patients		Age (years)	Metabolic syndrome	Height (M)	Weight (kg)
	Men	Women	Mean (range)	n (%)	Mean (range)	Mean (range)
Diabetic BMI 23–29	7	2	58 (17–77)	8/9 (88)	1.68 (1.55–1.75)	78 (67–88)
Non-diabetic BMI 23–29						
Diabetic BMI 30–34	12	4	54 (30–81)	15/16 (94	1.69 (1.39–1.85)	95 (60–115)
Non-diabetic BMI 30–34	4	8	36 (15–57)	1/12 (8)	1.68 (1.57–1.95)	92 (78–128)
Diabetic BMI 35–50	9	8	50 (24–72)	13/17 (76)	1.64 (1.47–1.80)	115 (88–137)
Non-diabetic BMI 35–50	5	20	40 (21–67)	6/25 (24)	1.63 (1.54–1.79)	110 (83–147)

After surgery, patients have liquid diet in the first week, semi-liquids in the second week, purée in third–fourth weeks, and normal diet 1 month after surgery.

Statistical Analysis

We used descriptive statistics (mean and standard deviation).

To test significant differences of parameters between the dif- ferent study groups, we used Student's t test for independent samples. The differences less than 5 % were considered sig- nificant. Analyses were performed using SPSS (version 21 for Windows, SPSS, Chicago, IL, USA) and Excel 2013.

Results

Preoperative Body Composition The epidemiological characteristics of the patients sample showed a wide range in BMI 23–50, age 17–81 years, and TBW 67–147 kg. There were also important differences in the incidence of MS (8–89 %) especially higher among diabetics (Table 1).

Regarding the baseline values of BC components (Table 2), first fact to note is the constancy of MM. Despite the wide range of TBW (67 to 147, 80 kg), MM varied only 8 kg (54– 62 kg). MM was around 6 kg more in diabetics than in non- diabetic patients for the same BMI range. That means that there are almost no differences between a person with 67 kg and another with 147 kg, while the big differences are due to FM, which range in mean between 22 and 52 kg.

The constancy of MM even in such wide ranges of TBW shows its metabolic importance to health and the need to keep it. VF also has constant levels, ranging from 12 (non-diabetic BMI 30–34) to 19 % (diabetics BMI 35–50) of the TBW. The diabetic patients had higher levels of VF than non-diabetics in each BMI range. In our sample, it is noteworthy that diabetic BMI 23–29 patients had a level of VF 17 % of TBW, whereas non-diabetic BMI 30–34 patients had only 15 %. This relative high percentage of VF in BMI 23–29 patients could explain their diabetes and high incidence of MS.

As can be seen in Table 2, BM increases parallel to BMI (1570 to 1998 kcal/day) and it is higher in diabetic than non- diabetic patients for the same BMI.

Dynamics of Changes in Body Composition During the First Postoperative Year

Total Weight Loss Tables 3 and 4 summarize the changes in BC during the first postoperative year. At first ten postopera- tive days, patients lost from 4 (BMI <30) to 9 kg (diabetics BMI 35–50). All of these patients had a liquid diet from 5 to 7 days before surgery and seven more days after surgery. At first month, patients lost 11 (BMI <30) to 17 kg (dia- betics BMI 35-50). At 3 months between 17 (BMI 23-29) to 28 kg (non-diabetic BMI 35-50). At 6 months, BMI <30 patients loss a mean of about 1 kg compared to 3 months, BMI 30-34 patients between 4 and 6 kg, and BMI 35-50 patients between 8 and 9 kg. Finally, one year after tailored BAGUA, BMI 23-29 patients have lost a mean of 2 kg compared to 6 months, BMI 30-34 a mean between 2 and 3 kg, and BMI 35-50 patients a mean of 6 kg. So, the weight loss is high and gradually until 3 months, while at 6 months began to stabilize in the lower BMI groups, while the loss still remain in higher BMI groups. Therefore, at 1 year, the rhythm of weight loss tends to be reduced proportionally to the baseline BMI.

Excess Weight Loss %EWL at 1 year after surgery is inversely related to preoperative BMI. In BMI 23–29 diabetics, the loss was 128 %, 84 % in BMI 30–34, and 76 % in BMI 35–50; while in non-diabetics, the loss was 91 % for BMI 30–34 and 81 % for BMI 35–50. That is, diabetics lost between 5 and 7 % less %EWL than non-diabetics (Table 4).

Muscle Mass Loss In our patient sample, diabetic patients had more MM than non-diabetics patients for the same BMI (Table 2). BMI 23–29 diabetics lost a mean of 8 kg of MM

Table 2 Preoperative and postoperative body composition in the five BMI range groups

BMI range groups	Period	Weight (kg)		BMI		MM (kg)		FM (kg)		Bone M (kg)		VF (kg)		BM (kcal/day)		TW (kg)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Diabetics BMI 23-29	Preop	78	8	28	3	54	8	22	8	2.6	0.5	13	3	1,570	185	40	5
	Postop	58	8	20	2	46	8	9	3	2.5	0.4	6	2	1,318	187	33	7
Non-diabetics BMI 23-29	Preop																
	Postop																
Diabetics BMI 30-34	Preop	95	17	33	2	62	11	37	14	3.1	0.7	14	3	1,841	360	47	9
	Postop	68	14	24	2	53	11	12	8	3	0.7	6	2	1,488	278	38	8
Non-diabetics BMI 30-34	Preop	92	15	32	1	55	10	35	14	2.8	0.6	11	2	1,785	353	44	9
	Postop	65	14	23	2	49	9	10	4	2.8	0.5	5	2	1,484	296	34	6
Diabetics BMI 35-50	Preop	115	14	42	3	61	13	50	10	3.1	0.7	22	2	1,998	368	48	11
	Postop	73	11	27	3	51	9	18	6	3	0.7	11	2	1,513	244	36	8
Non-diabetics BMI 35-50	Preop	110	14	41	4	55	6	52	10	2.9	0.4	18	4	1,852	232	44	6
	Postop	68	12	26	4	47	7	19	7	2.8	0.5	8	2	1,430	152	36	6

hey represent mean values (Mean) and standard deviation (SD) in kilograms (kg) of the weight, body mass index (BMI), muscle mass (MM), fat mass (FM), bone mass (Bone M), visceral fat (VF), basal metabolism (BM), and total water (TW) of the patients in the preoperative (Preop) and postoperative (Postop) periods after tailored BAGUA

during the first year. From these, 5 kg is lost during the first month and the other 3 kg in the first 3 months (Table 3). After 3 months, this group did not lose more MM.

BMI 30–34 diabetic patients lost a mean of 9 kg of MM, while non-diabetics lost only 6 kg (33 % less). Finally, BMI 35–50 diabetic patients lost a mean of 9 kg, and non-diabetics lost 8 kg (11 % less). In both cases, the loss was progressive during the 12 months.

In summary, MM loss in the first postoperative year after BAGUA ranged between 12 and 17 % (Table 4) being

Table 3: Dynamic of changes of body composition during the first postoperative year							
BMI range groups	**BC Components**	**Evaluation Appointment (kg±SD)**					
		Preop	**10 days**	**1 month**	**3 months**	**6 months**	**12 months**
Diabetics BMI 23-29	Weight	78±8	74±8	67±8	61±9	59±9	56±8
	Muscle mass	54±8	53±8	49±7	46±7	46±8	46±8
Non-diabetics BMI 23-29	Fat mass Weight Muscle mass Fat mass	22±8	19±8	16±7	12±5	11±4	9±3
Diabetics BMI 30-34	Weight	95±17	89±17	83±16	77±16	73±14	68±14
	Muscle mass	62±11	61±11	58±11	56±12	54±11	53±11
	Fat mass	37±14	31±11	26±9	19±8	15±8	12±8
Non-diabetics BMI 30-34	Weight	92±15	86±15	79±14	73±14	69±15	65±14
	Muscle mass	55±10	54±10	55±9	53±9	52±9	49±9
	Fat mass	35±14	32±13	24±9	17±6	13±5	10±4
Diabetics BMI 35-50	Weight	115±14	106±15	98±14	88±12	79±11	73±11
	Muscle mass	61±13	62±12	59±11	56±10	53±9	51±9
	Fat mass	50±10	42±9	35±8	28±7	22±5	18±6
Non-diabetics BMI 35-50	Weight	110±14	103±15	94±14	82±12	74±11	68±12
	Muscle mass	55±6	55±8	54±9	51±8	49±7	47±7
	Fat mass	52±10	45±10	37±9	29±7	22±6	19±7

Figures represent the mean value +/− standard deviation (SD) of weight, muscle mass, and fat mass in kilograms (kg), in the evaluation appointment during the first postoperative year after tailored BAGUA, in the different groups of patients

Table 4 Percentage of reduction in body composition changes 1 year after tailored BAGUA surgery							
Group of patients	**TWL after a year (kg)**	**%EWL**	**MM (%)**	**FM (%)**	**VF (%)**	**TW (%)**	**BM (%)**
Diabetics BMI 23-29	20.1	128	16	57	54	18	16
Non-diabetics BMI 23-29 **Diabetics BMI 30-34**	27.2	84	14	69	57	19	19
Non-diabetics BMI 30-34	27.2	91	12	71	55	23	17
Diabetics BMI 35-50	41.9	76	17	65	50	25	24
Non-diabetics BMI 35-50	41.7	81	16	64	56	18	23

Figure represents mean values in kilograms (kg) of total weight loss (TWL), and percentage (%) of excess weight loss (%EWL), muscle mass (MM), fat mass (FM), visceral fat level (VF), total water (TW), and basal metabolism (BM) of patients a year after tailored BAGUA surgery always higher in diabetic than non-diabetic patients. That means, it maintains very steady in comparison with TBW and FM loss.

Fat Mass Loss FM loss during the first postoperative year depended on the preoperative BMI: 13 kg (57 % of preoper- ative FM) in BMI 23–29 diabetics, 25 kg in BMI 30–34 (69 % diabetic, 71 % non-diabetic), and 32–33 kg in BMI 35–50 (65 % diabetic and 64 % non-diabetic) (Tables 3 and 4). That means most of TWL is FM.

Influence of Bearing MS in the Changes of BC After Tailored BAGUA

The relationship between presence of preoperative MS and changes in BC after BAGUA has shown how MS patients were significantly older in all ranges of BMI (p<0.000) (Table 5). BMI 23–29 patients who had MS had more FM (p<0.001). Patients with MS and BMI 30–34 had significant- ly more MM, bone mass, and VF. Finally, BMI 35–50 patients with MS had higher MM and VF. In summary, preoperative

presence of MS have an important influence on changes in BC after tailored BAGUA.

Influence of Diabetes Mellitus-Related Complications in the Changes of BC After Tailored BAGUA Patients in BMI 23–29 range group proved to be most affected (p=0.000) with complications of diabetes associated with increasing age and decreasing bone mass and MM. In BMI 30–34, we only found relationship with increasing age (p= 0.000) (Table 6).

Discussion

The incorporation of bariatric surgery procedures for the specific purpose of treating T2DM opened the question of its possible side effects on the nutritional status and BC when it is performed in patients below the BMI limit used until now (BMI >35), even more when we had to treat diabetics with BMI <30.

Table 5 Changes of body composition in presence or absence of metabolic syndrome of different patient groups

		BMI 23-29				**BMI 30-34**				**BMI35-50**			
	MS	n	Preop	1Y	P	n	Preop	1Y	p	n	Preop	1Y	p
Age	No		48	48	0.002*	12	35	35	0.000*	23	39	39	0.000*
	Yes		63	63		16	55	55		19	50	50	
Muscle mass (kg)	No		57	43	0.946	12	56	48	0.003*	23	56	46	0.000*
	Yes		53	47		16	62	53		19	60	51	
Fat mass (kg)	No		17	7	0.001*	12	37	11	0.591	23	51	18	0.670
	Yes		24	11		16	36	11		19	52	19	
Visceral fat (kg)	No		11	5	0.080	12	11	5	0.000*	23	19	8	0.001*
	Yes		14	7		16	14	6		19	21	10	
Bone mass (kg)	No		2.4	2.4	0.014	12	2.8	2.7	0.001*	23	2.9	2.8	0.015
	Yes		2.7	2.6		16	3.1	3.0		19	3.1	2.9	

*Figure represents mean values summarized in the first to the last evaluation appointment according to the number of patients (n), in the preoperative (Preop) and 1 year (1Y) after tailored BAGUA surgery by BMI groups with the presence of metabolic syndrome (MS) *Statistically significant (p<0.05)*

Table 6 Influence of Diabetes Mellitus of related complications in the changes of body composition after tailored BAGUA

		BMI 23-29				BMI 30-34				BMI 35-50			
	Diabetes-related complications	n	Preop	1Y	p	n	Preop	1Y	p	n	Preop	1Y	p
Age (years)	No	6	52	53	0.000*	7	49	50	0.000*	15	51	52	0.043
	Yes	3	69	70		9	58	59		2	44	45	
Weight (kg)	No	6	79	59	0.095	7	101	70	0.237	15	117	75	0.005
	Yes	3	74	54		9	91	67		2	100	70	
Fat mass (kg)	No	6	21	9	0.524	7	37	10	0.595	15	50	18	0.465
	Yes	3	23	11		9	37	12		2	48	15	
Muscle mass (kg)	No	6	58	49	0.000*	7	61	50	0.208	15	61	51	0.775
	Yes	3	48	38		9	62	54		2	63	49	
Visceral fat (kg)	No	6	14	6	0.052	7	14	6	0.630	15	23	12	0.341
	Yes	3	11	6		9	14	6		2	22	10	
Bone mass (kg)	No	6	2.9	2.8	0.000*	7	3.2	3.0	0.946	15	3.1	3.0	0.493
	Yes	3	2.1	2.1		9	3.0	3.0		2	3.4	3.0	

Figure represents mean values summarized in the first to the last evaluation appointment according to the number of patients (n), in the preoperative (Preop) and 1 year (1Y) after tailored BAGUA surgery by BMI groups with the presence of complications related to diabetes *Statistically significant ($p<0.05$)

For us and other groups [25, 26] that have always tailored bariatric surgery to the patient's necessities, we found easy to adapt our procedure for lower BMI. We just shortened the length of the excluded intestine to reduce the degree of mal- absorption and made a larger reservoir to decrease the degree of restriction, given that we used only one anastomosis, the gastro-jejunal, as opposed to Roux-en-Y gastric bypass that needs two anastomoses: gastro-jejunal and jejuno-jejunal.

To validate the effect of different degrees of malabsorption (see "Methods" section) on weight loss and BC, we used bio- impedance measures in short intervals throughout the first postoperative year in which major changes occur.

We used patients with BMI 35–50 as a control group of the lower BMI 23–34. The first postoperative BC changes are the same for all BMI range groups and coincide with the transition diet during the first month, and the next 2 months period of

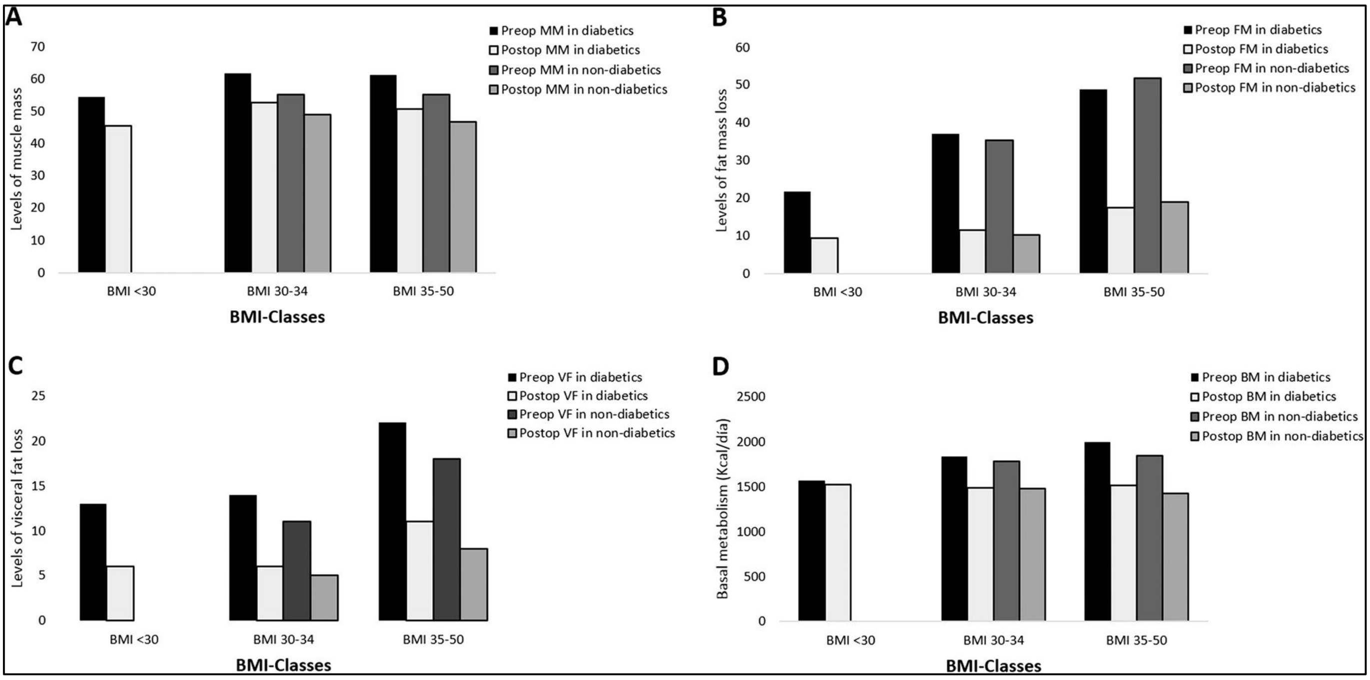

Fig. 1 The data represent the differences between diabetic and non- diabetic patients in the mean of BC parameters considered in the study. a represents %EWL in the postoperative appointment (1 year). B represents MM, c represents FM, d represents VF, and e represents BM in the different BMI-classes in preoperative and postoperative appoint- ment (1 year of follow-up)

gradual recovery of normal diet. After 3 months, the evolution is different according to the amount of FM to be lost and the degree of proportional malabsorption we have done to get it.

The loss of MM is minimal, equal for all ranges of BMI, and independent of the percentage of EWL, around 15 % of TBW loss, which means almost half of what tolerable [1].

This can be explained by the ability of tailored BAGUA patients to have a complete diet including proteins and a good intestinal absorption, opposite to what happens in other bar- iatric procedures in which it is necessary to administer growth hormone [27]. Diabetics lose less weight and more MM than non-diabetics may be related to disorders of energy metabo- lism in liver, adipose, and muscle tissue [28].

BM increases in higher BMI, especially of diabetics. After surgery, FM registered an important decreased, but not the TW and MM. Over time, FM decreases a slower rate propor- tionally to preoperative BMI. One year after surgery, we appreciate a spectacular BC change compared with preopera- tive data, where non-diabetic patients with higher BMI regis- tered bigger changes in %EWL and FM.

BC changes during first year after BAGUA mainly due to the decreased FM including VF contributes to solve diabetes and MS.

The importance of this work is because there are no com- parative studies analyzing the evolution and final BC in pa- tients with so wide BMI 23–50, even less comparing diabetics and non-diabetics with or without MS after a tailored bypass surgery over time.

During the postoperative follow-up, BC serves us to eval- uate if the evolution of weight loss was appropriate and for correcting it in case of deviations. In these cases, we correct their diet and exercise, controlling them in shorter period until the deviation reach the expected level.

Proceeding in this way, the effect of tailoring BAGUA is quite impressive. We performed it in patients with normal BMI 23 and up, obtaining a healthy weight loss in the same way as in obese patients with amazing results on the resolution of diabetes mellitus (DM) and MS.

Studies with greater sample are needed to fully understand healthy weight loss, but this work is a watershed of conducting BC in all patients undergoing bariatric surgery.

After tailored BAGUA, patients show a significant FM loss but no MM. These results validate the way in how we tailor BAGUA as a safe and effective surgical technique for weight loss and diabetes and/or MS resolution in low BMI patients.

Conclusions

It is important to perform tailored bariatric procedures accord- ing to the necessities of the patients, analyzing BC prior and after surgery over time in order to watch out a healthy weight loss especially in diabetes and in obesity surgery too.

After BAGUA, the amount of MM is steady, but the amount of FM is highly variable. BM is equal among patients.

Diabetic patients lose less weight and VF, but more MM.

These different BC changes, compared with no diabetics in the same BMI, have no consequences for the resolution or improvement of DM and MS (Fig. 1).

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