

Original Article

Lung volumes, lung capacities and respiratory muscle strength following gastroplasty*

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Background: Gastroplasty has been increasingly used in the treatment of morbidly obese patients, who typically present pronounced alterations in lung volume and capacity.

Objective: To evaluate post-gastroplasty lung volume, lung capacity, respiratory muscle strength and respiratory pattern, as well as any postoperative pulmonary complications.

Method: 21 patients (3 of them men), with an average age of 39 ± 9.7 years and an average body mass index of 50.4 kg/m^2 , all candidates for gastroplasty, were evaluated during the preoperative period and again on the first, third and fifth postoperative days. Tidal volume, vital capacity, minute volume, maximal expiratory pressure and maximal inspiratory pressure, as well as chest and waist circumferences, were measured. Postoperative pulmonary complications and mortality were assessed.

Results: On the first and third postoperative days, respectively, there were drops of 47% and 30.5% in vital capacity, 18% and 12.5% in minute volume, 28% and 21% in tidal volume, 47% and 32% in the diaphragmatic index, 51% and 26% in maximal inspiratory pressure, and 39.5% and 26% in maximal expiratory pressure ($p < 0.05$). On the fifth postoperative day, all variables analyzed were higher than on the first postoperative day, indicating a linear increase, with only tidal volume, minute volume diaphragmatic index returning to preoperative values. The incidence of postoperative pulmonary complications was 4.7%, and there were no deaths.

Conclusion: Patients submitted to gastroplasty present reduced pulmonary function, following a pattern quite similar to that previously observed following other types of upper abdominal surgery.

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Key words: Gastroplasty. Obesity. Respiratory function tests. Postoperative care.

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INTRODUCTION

Obesity is defined as an increase in adipose tissue, which is frequently related to health risks⁽¹⁾. The prevalence of morbidly obese patients has been increasing dramatically in Brazil, where the obese population has grown by approximately 90% in the past 30 years⁽¹⁻⁴⁾.

Various indices can be used to diagnose obesity. The most common of these is body mass index (BMI), which is defined as the weight in kilograms divided by the square of the height in meters⁽⁵⁻⁷⁾. Values of BMI higher than 40 kg/m² indicate morbid obesity, and surgical treatment is recommended for weight reduction in these cases⁽¹⁾. Among the surgical procedures that can be performed, gastroplasty, as proposed by Capella, allows greater weight reduction, an average of approximately 40% of the excess weight within 12 months, and a consequent decrease in the accompanying morbidity. This is currently the surgical procedure of choice for the treatment of morbid obesity^(8,9).

There are various factors that interfere with the respiratory mechanics of obese patients, resulting in lower lung volumes and capacities, especially expiratory reserve volume and functional residual capacity⁽¹⁰⁻¹⁴⁾. Excess adipose tissue causes mechanical compression of the diaphragm, lungs and chest cavity, leading to restrictive respiratory insufficiency. Obesity also causes a decrease in total respiratory system compliance and an increase in pulmonary resistance⁽¹⁰⁻¹⁴⁾.

Due to the inefficacy of respiratory muscles, muscle strength and endurance may be reduced when compared to nonobese patients⁽¹⁴⁾. All of these factors lead to overload, increasing respiratory work, oxygen consumption and respiratory energy expenditure⁽¹⁴⁾.

When obese patients are submitted to upper abdominal surgery, it would be expected that they would be more susceptible to pulmonary complications from anesthesia and from the surgical procedure itself⁽¹⁵⁻¹⁶⁾. In obese patients, anesthesia accentuates the reduced functional residual capacity, promoting early narrowing of the small airways, causing a greater degree of hypoxemia and higher incidence of atelectasis than in nonobese patients⁽¹⁵⁻¹⁶⁾.

In nonobese patients submitted to upper abdominal surgery (UAS), changes in respiratory mechanics, respiratory pattern, gas exchanges and lung defense mechanisms occur during the postoperative period, often leading to postoperative pulmonary complications (PPCs)⁽¹⁷⁻¹⁸⁾. It seems reasonable to expect that, in morbidly obese patients submitted to UAS, these

alterations would be more pronounced, thereby leading to a higher incidence of PPCs in this population.

The objective of this study was to evaluate the extent of the decrease in lung volumes and lung capacities as well as in maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) in a group of obese patients submitted to gastroplasty as proposed by Capella, and to monitor these variables, together with the incidence of pulmonary complications and mortality, during the postoperative period.

METHOD

We selected 30 patients, all candidates for gastroplasty as proposed by Capella, admitted to the Gastric Surgery Infirmary of the Hospital São Paulo (Unifesp/EPM) between August 2001 and August 2002. The Committee for the Ethical Treatment of Research Animals of the institution approved the study.

The inclusion criteria for patients were being older than 18 years of age, having no previous acute or chronic pulmonary disease, presenting normal spirometry results and being able to perform the physical therapy maneuvers and measures. Exclusion criteria were alteration of surgical technique during the intraoperative period, requiring mechanical ventilation for more than 48 hours, surgical reintervention and laparoscopic surgery.

Using these criteria, of the 30 initially selected patients, only 21 were included. Of the 9 excluded patients, 1 was diagnosed with chronic obstructive pulmonary disease, 3 were unable to perform the physical therapy maneuvers, and 5 were not submitted to the surgical procedure due to a lack of beds in the intensive care unit. These patients were later submitted to surgery, although the data collection period for the present study had passed.

Preoperative evaluation included collecting clinical histories, performing physical examinations and taking chest X-rays, as well as determining of minute volume (MV), tidal volume, vital capacity (VC) and respiratory muscle strength (MIP, MEP). Spirometry was carried out using an Ohmeda spirometer (model 121; Ohmeda, Oxnard, CA, USA). Patients remained seated during all measurements.

A nose clip was used, and a mouthpiece was connected to the spirometer. Patients were asked to breathe easily for one minute and MV was determined. Tidal volume was determined by dividing MV by the respiratory frequency, whereas

VC was measured by asking the patients to make a maximum forced inspiration followed by a maximum non-forced expiration.

We obtained MIP and MEP using a vacuum manometer (MTR, São Paulo, Brazil). Three measurements were made, each starting from functional residual capacity, and the highest of the three was recorded. The diaphragmatic index was calculated using the formula $DI = \frac{\Delta AB}{\Delta AB + \Delta TC}$, in which DI is the diaphragmatic index and Δ is the difference between the abdominal (AB) and thoracic (TC) circumferences determined at the end of inspiration and calm expiration⁽¹⁷⁾.

After the preoperative evaluation, patients were oriented regarding the surgical procedure, the need for respiratory exercises and the importance of coughing and early mobilization. Intraoperative data were collected from the surgery and anesthesia records.

During the postoperative period, patients were submitted to respiratory therapy once a day and spirometry and respiratory muscle strength measurements were taken on the first, third and fifth postoperative days.

The incidence of pneumonia, tracheobronchitis, atelectasis, acute respiratory insufficiency, bronchospasm and pulmonary thromboembolism, as well as the need for mechanical ventilation or intubation for more than 48 hours, were all considered PPCs.

For the statistical analysis, we used variance analyses with repeated measurements in order to compare the mean values of the variables of interest on the various evaluation days (preoperative, first, third and fifth postoperative days). When there were statistically significant differences, multiple comparisons using Bonferroni corrections were made in order to detect the pattern of difference. In order to compare whether postoperative values differed from preoperative values and whether baseline values were restored on the last day of assessment, we tested the following hypotheses: $H_0 = \mu_{Pre} = \mu_{1PO}$; $H_0 = \mu_{Pre} = \mu_{3PO}$; and $H_0 = \mu_{Pre} = \mu_{5PO}$. Finally, in order to determine whether the return to baseline values occurred in a linear fashion over the three days postoperative observation, we tested the hypothesis $H_0 = \mu_{1PO} + \mu_{5PO} = 2 \cdot \mu_{3PO}$. Data were plotted on box-plot graphs. The level of significance was set at 5%.

RESULTS

The mean age of the 21 patients studied was 39 ± 9.7 years. The sample included 3 males and 18 females (14.2% and 85.7%, respectively). Mean preoperative

BMI was 50.4 ± 7.6 kg/m². Of the 21 patients, 3 (14.2%) were smokers, 6 (28.5%) were former smokers and 12 (57.1%) were nonsmokers. The most common clinical diseases were arterial hypertension ($n = 12$; 57.1%) and diabetes mellitus ($n = 6$; 28.5%).

Means and standard deviations of respiratory frequency, tidal volume and MV were 17.8 ± 3.3 rpm, 0.7 ± 0.2 L and 12.3 ± 4.1 L, respectively. Mean VC was 3.1 ± 0.7 L and the percent of predicted was 88.7 ± 14.5 . The degree of correlation (r) between VC and BMI was -0.66 . Means and standard deviations of MIP and MEP were -95.5 ± 26.0 cmH₂O and 96.2 ± 25.2 cmH₂O, respectively. Mean percent of predicted for MIP and MEP reference values for obese patients was 95 ± 26.7 and 98.4 ± 26.8 (Table 1).

Anesthesia time was of 300 ± 47.5 minutes and there were no unexpected incidents during the surgical procedures.

In relation to the baseline (preoperative) value, mean tidal volume dropped by 28% on the first postoperative day and by 21% on the third postoperative day ($p < 0.001$ and $p = 0.028$). However, on the fifth postoperative day, values were similar to those seen in the preoperative period ($p = 0.231$) (Table 2).

Mean MV dropped by 18% ($p = 0.075$) on the first postoperative day in comparison to the baseline value. On the third and fifth postoperative days, values were again similar to the baseline values ($p = 0.416$ and $p = 0.807$). There was a linear increase in mean MV from the first to the fifth postoperative days ($p = 0.712$) (Table 2).

Mean VC dropped by 47%, 30.5% and 14.6%, respectively on the first, third and fifth postoperative days ($p < 0.001$, $p < 0.001$ and $p = 0.050$) in relation to preoperative values. There was also a linear increase in mean VC from the first to the fifth postoperative days ($p = 0.948$). On the first and the third postoperative days, there were drops of 47% and 32% in the mean diaphragmatic index ($p = 0.001$ and $p = 0.010$), respectively. On the fifth postoperative day, these values returned to those seen in the preoperative period ($p = 0.259$), indicating a linear increase from the first to the fifth postoperative days ($p = 0.774$) (Table 2, Figure 1).

Analysis of respiratory muscle strength revealed drops of 51%, 26% and 14% in the MIP on the first, third and fifth postoperative days, respectively, in relation to preoperative values ($p < 0.001$, $p < 0.001$ and $p = 0.028$). There were drops of 39%, 26% and 15% in mean MEP on the first, third and

TABLE 1

Absolute and percentage of predicted maximal inspiratory pressure, maximal expiratory pressure and vital capacity values, as well as diaphragmatic index values, for the 21 morbidly obese patients submitted to gastroplasty as proposed by Capella

Patient	MIP		MEP		VC		DI
	cmH ₂ O	%	cmH ₂ O	%	L	%	
1	-100	115,0	125	146,3	3,60	116,8	0,6
2	-90	103,4	60	70,2	2,87	95,6	0,5
3	-50	63,0	50	60,2	2,30	73,9	0,6
4*	-100	87,0	100	80,0	4,30	85,1	0,8
5	-70	88,2	100	120,4	2,80	96,8	0,6
6	-60	59,0	70	61,4	3,90	108,6	0,6
7	-75	82,0	125	124,2	3,80	72,9	0,6
8	-100	98,4	80	70,1	4,00	99,7	0,6
9	-80	87,5	80	99,4	2,80	84,3	1,6
10	-85	83,6	80	93,6	3,15	83,1	1,5
11	-100	109,2	100	96,3	3,30	94,5	0,5
12	-75	86,2	80	144,5	2,50	75,0	0,4
13*	-150	110,0	150	107,0	3,20	70,4	0,6
14	-100	126,0	80	108,5	3,05	89,7	0,7
15	-75	94,5	120	109,3	2,30	88,8	0,6
16*	-100	77,5	120	81,6	4,45	94,2	0,6
17	-110	138,7	90	146,3	3,84	118,8	0,5
18	-120	69,0	110	99,4	2,40	69,7	0,4
19	-125	56,4	125	74,5	2,70	89,1	0,6
20	-150	164,0	100	99,4	3,60	96,7	0,3
21	-90	101,7	75	74,5	2,15	58,4	0,6
Mean	-95,5	95,0	96,2	98,4	3,14	88,7	0,6
DP	26,0	26,7	25,2	26,8	0,70	14,48	0,3

* Male patients.

MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; VC: vital capacity; DI: diaphragmatic index; SD: standard deviation

fifth postoperative days, respectively, also in relation to preoperative values ($p < 0.001$, $p < 0.001$ and $p = 0.072$). There were also linear increases in MIP and MEP from the first to the fifth postoperative days ($p = 0.684$, $p = 0.071$) (Table 2; Figure 2).

The incidence of PPCs was low in this study (4.7%). One patient was diagnosed with pulmonary thromboembolism. There were no deaths.

DISCUSSION

Morbid obesity has been correlated with alterations in the pulmonary function, which is more dramatically affected in proportion to the amount of adipose tissue accumulated⁽¹⁴⁾. In our study, mean BMI was 50.4 kg/m², and there was high variability in preoperative VC, MIP and MEP values. We observed that VC declined exponentially with increased BMI. Therefore, the greatest alterations in

emphasize the fact that, although the sample size was small, the number of males was much lower than that of females, which could have affected this finding.

The function of respiratory muscles and diaphragmatic movement is affected by obesity. This is caused by the restricted expansion of the chest cavity and lungs⁽¹³⁻¹⁴⁾. In our study, there was high variability between preoperative MIP and MEP values, some patients presenting low muscle strength values and others presenting normal or even higher than predicted values. This minor effect on MIP and MEP values can be explained by the fact that obese patients present higher overload, which promotes a training effect on the respiratory muscles and could, thereby, result in less dramatic drops in MIP and MEP. In 1999, Neder et al. carried out a study in which they proposed reference values for MIP and MEP in nonobese patients⁽²²⁾. When we compared these values with those

TABLE 2

Mean of absolute values and percentage decrease in relation to the preoperative values of respiratory frequency, tidal volume, minute volume, vital capacity, maximal inspiratory pressure, maximal expiratory pressure and diaphragmatic index on the first, third and fifth postoperative days for the 21 morbidly obese patients submitted to gastroplasty as proposed by Capella

Variable/days	Pré-op		1st POD		3rd POD		5th POD	
	A	%	A	%	A	%	A	%
RF (rpm)	17,8	100	20,9	117	19,8	111	19,4	109
TV (L)	0,7	100	0,5	72	0,5	79	0,6	91
MV (L)	12,3	100	10,1	82	10,8	88	12,1	99
VC (L)	3,1	100	1,6	53	2,2	69	2,7	85
MIP (cmH ₂ O)	-95,5	100	-46,7	49	-70,2	74	-82,1	86
MEP (cmH ₂ O)	96,2	100	58,3	61	71,4	74	81,4	85
DI	0,6	100	0,3	53	0,4	68	0,5	77

Pre-op: preoperative (baseline); POD: postoperative day; RF: respiratory frequency; TV: tidal volume; MV: minute volume; VC: vital capacity; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; DI: diaphragmatic index; A: Absolute

of our sample, we noticed that mean MIP and MEP were practically within normality for non-obese patients. However, when we studied these values individually, we realized there were great discrepancies, with values much lower or higher than predicted. These variations suggest that the predictive values for respiratory muscle strength for nonobese patients should not be used for obese patients and that further studies should be carried out in order to determine specific reference values for this population.

There have been very few studies of pulmonary alterations in the postoperative period of morbidly obese patients submitted to UAS^(11,23-24). In 2002, Ebeo et al. compared pulmonary function during the preoperative and postoperative periods in a group of obese patients submitted to gastroplasty and reported drops of up to 55% in forced vital capacity and in forced expiratory volume in one second⁽²⁴⁾.

In our study, all of the variables showed drops from 20% to 50% on the first postoperative day in relation to the preoperative values, and only VC, MIP and MEP had not returned to their initial values by the fifth postoperative day.

Obese patients in the postoperative period presented shallower breathing, higher respiratory frequency and lower tidal volume, exactly as observed in nonobese patients. The diaphragmatic index may reflect this alteration in the respiratory pattern. In 2000, Chiavegato et al. reported that this index, not yet validated in the literature, expressed alteration in the respiratory pattern and the predominance of costal breathing during the

postoperative period in nonobese patients submitted to cholecystectomy⁽¹⁷⁾.

Obese patients would be expected to present more dramatic drops in lung volume and lung capacity and to require longer periods for the recuperation of these values. However, with these results, we noticed that the drop in pulmonary function in this group of patients was very similar to that seen in nonobese patients submitted to UAS, as we can see in Chart 1^(23,25-27). The lack of a control group in this study is explained by the fact that this surgical procedure is only carried out in obese patients. Based on these results, we may suggest that the evolution of lung volumes and lung capacities can be better reflected by VC and by respiratory muscle strength since those were the variables that presented the more dramatic drops.

As in nonobese patients, the most well-accepted explanation for these drops is reflex inhibition of the diaphragm, resulting in diaphragmatic paresis, which in turn promotes a restrictive pulmonary pattern, potentially contributing to the occurrence of PPCs^(17,27).

A combination of other factors, such as age, surgical time, anesthesia and a recumbent position during surgery, may accentuate these alterations^(17,19).

In some studies, being older than 65 has been associated with higher incidence of PPCs due to the presence of comorbidities⁽¹⁷⁾. However, this fact showed little importance in our study since the mean age of patients was 39 ± 9.7 years.

Prolonged surgical and anesthesia times may cause deleterious effects on the respiratory system, such as alterations in gas exchange and pulmonary

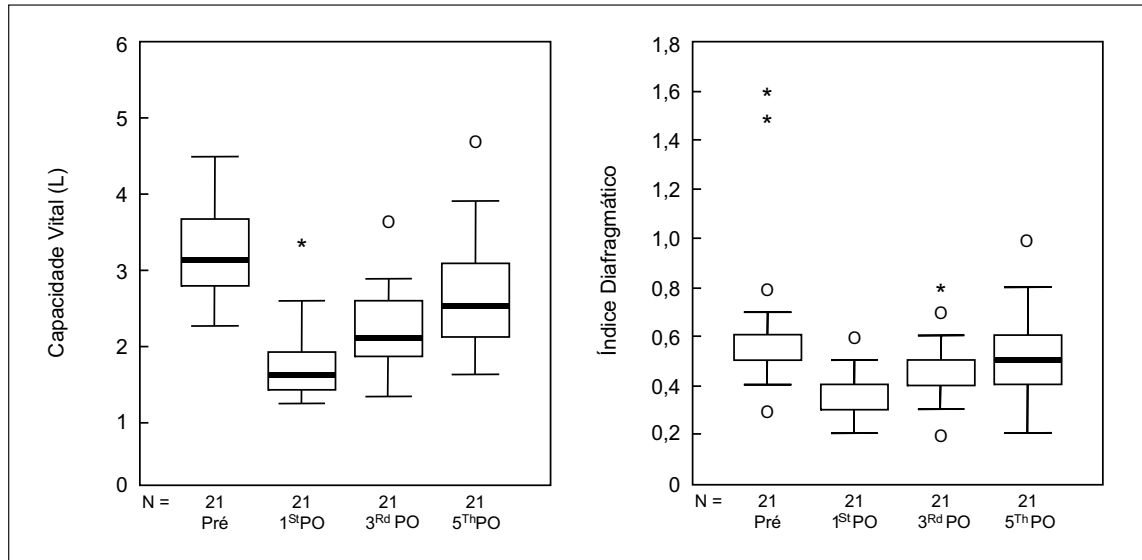


Figure 1. Mean vital capacity and diaphragmatic index of 21 morbidly obese patients submitted to gastroplasty as proposed by Capella, during the preoperative period, and on the first, third and fifth postoperative days (** and 'o' indicate discrepancy)

Pre-op: preoperative; POD: postoperative day

mechanics, which would increase the chances for PPCs⁽¹⁷⁾. These effects are more evident in obese patients, making them more susceptible to PPCs⁽¹⁶⁾. In 2002, Eichenberg et al., in comparing obese and nonobese patients submitted to general anesthesia, reported that obese patients presented a higher incidence of atelectasis in the postoperative period than did nonobese patients⁽¹⁶⁾.

In our study, mean surgical time was 300 ± 47.5 minutes. Although some studies at our institution have shown a correlation between the incidence of PPCs and surgical time longer than 210 minutes, the incidence in the present study was low.

Tobacco smoking increases the incidence of PPCs by damaging pulmonary defense mechanisms^(17,19). In our study, there were 3 smokers (14.2%), 6 former smokers (28.5%) and 12 nonsmokers (57.1%). None of the smokers presented PPCs.

The incidence of PPCs during the postoperative period in nonobese patients submitted to UAS ranges from 10% to 80%⁽¹⁹⁾. Morbidly obese patients submitted to UAS could present a higher risk of developing PPC since they would already present limited pulmonary function. However, as we observed, not every obese patient presented markedly limited pulmonary function. In our study,

only one patient presented a PPC, diagnosed as pulmonary thromboembolism. Patients submitted to bariatric surgery present moderate to high risk of pulmonary thromboembolism, caused by obesity itself, sedentary lifestyle, venous stasis or changes in coagulation parameters. In addition, remaining in the supine position for longer than 30 minutes during surgery increases venous stasis⁽²⁸⁾.

All patients were submitted to respiratory therapy once a day during the pre- and postoperative periods. During the preoperative period, patients were given information regarding the surgical incision, the importance of coughing, early mobilization and respiratory therapy exercises. However, unlike other surgical patients, these patients were aware of the importance of respiratory therapy prior to hospitalization, since they were periodically examined by a multidisciplinary outpatient group while awaiting surgery. The patients were also aware of the high risk for postoperative pulmonary and thromboembolic complications. Postoperative therapy consisted of respiratory exercises associated with free global active exercises, assisted cough and mobilization. The patient who presented a PPC was submitted to the same exercises in combination with positive airway pressure.

Studies have proven that the use of respiratory therapy, regardless of the technique, is more efficacious in the prevention of PPCs than is

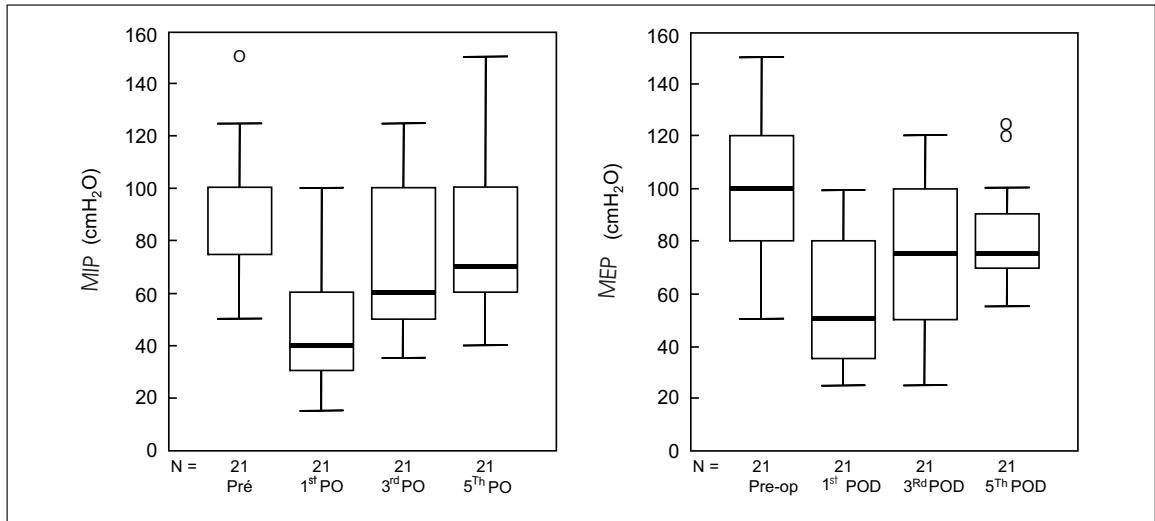


Figure 2. Mean MIP and MEP of 21 morbidly obese patients submitted to gastroplasty as proposed by Capella during the preoperative period and on the first, third and fifth postoperative days (** and 'o' indicate discrepancy) Pre-op: preoperative; POD: postoperative day

withholding such therapy. Ideally, treatments should be given every two hours⁽²⁹⁾.

The hospital in which the study was carried out is a university hospital, with ever increasing difficulties and shortages of staff for pre- and postoperative care. Therefore, since it was not possible to carry out more than one respiratory therapy session per day, we expected a higher incidence of PPC. The low incidence of PPC in

this group of patients might have been due to the prior awareness of the importance of respiratory therapy exercises, even without supervision.

We can conclude that, in patients submitted to gastroplasty as proposed by Capella for the treatment of morbidly obesity, there was a postoperative drop in lung volumes and capacities, as well as in respiratory muscle strength. These

CHART 1

Comparison of pulmonary function after upper abdominal surgery in obese patients and nonobese patients

Article/Year	Type of study	Sample (n)	Results (1st POD)	Recovery functional (%)
Dureui et al. ¹²⁷ /1987	Prospective	n = 23	↓ VC = 60%	7
		UAS	↓ DI = 40%	
Cardim et al. ³⁰ /1991	Prospective	n = 43	↓ VC = 57,4%	< 7
		EL	↓ FEV ₁ = 32,4%	
Chiavegato et al. ¹⁷ /2000	Prospective	n = 20	↓ VC = 36%	3
		LC	↓ DI = 36%	
			↓ MIP = 47%	
			↓ MEP = 39%	
Paisani et al./2004	Prospective	n = 21CG	↓ VC = 47%	< 5 Except DI
			↓ DI = 47%	
			↓ MIP = 51%	
			↓ MEP = 47%	

POD: postoperative day; UAS: upper abdominal surgery; EL: exploratory laparotomy; LC: laparoscopic cholecystectomy; CG: conventional gastroplasty; VC: vital capacity; DI: diaphragmatic index; FEV₁: forced expiratory volume in one second; MIP maximal inspiratory pressure; MEP: maximal expiratory pressure

results are similar to those reported for nonobese patients submitted to UAS. In addition, the incidence of postoperative complications was low in our population sample. We observed that pre- and postoperative respiratory therapy is extremely helpful in the prevention of PPCs, and we recommend that it be used as early as possible. However, since this was not the objective of the present study, further studies are needed in order to evaluate the true role of respiratory therapy in the early recovery of the pulmonary function.

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