

# Bariatric Surgery in Adolescents: Preliminary 1-year Results with a Novel Technique (Santoro III)

Manoel Carlos P. Velhote · Durval Damiani

Received: 13 February 2008 / Accepted: 27 March 2008 / Published online: 1 May 2008  
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## Abstract

**Background** Bariatric surgery (BS) was recognized as the only treatment for morbid obesity in adolescents. Classic surgical procedures are based on mechanical restriction and/or malabsorption, resulting in a large number of possible complications and demanding lifelong medical attention. A novel BS design, the Santoro III procedure, relies on modifying secretion of the satiogenic hormones GLP-1 and PYY. This approach avoids common BS complications such as prostheses, narrow anastomoses, excluded segments, and malabsorption. This study describes the 1-year follow-up of the first ten adolescents operated on using the Santoro III technique in a pediatric surgical service.

**Methods** Ten adolescents, mean age  $16.1 \pm 1.7$  years with body mass index (BMI) greater than  $40 \text{ kg/m}^2$  (range 44 to  $72 \text{ kg/m}^2$ ), refractory to at least 2 years of medical weight loss treatment were selected by a multidisciplinary team to undergo BS. This operation consists of a sleeve gastrectomy with enteroomentectomy and partial gastro-ileal derivation.

**Results** After 1 year, mean body weight decreased from 140.3 to 88.6 kg, and BMI decreased from  $52.8 \pm 9.5 \text{ kg/m}^2$  to  $33.4 \pm 7.7 \text{ kg/m}^2$ , with percent of excess BMI lost as  $83.9 \pm 17.1\%$ . Glucose, insulin, total cholesterol, LDL-cholesterol, and triglyceride levels decreased significantly, while HDL-cholesterol, hemoglobin, and albumin levels remained unchanged. There were no mortalities or reoperations. The two complications that presented during the trial (intraoperative abscess and polyneuritis) resolved with medical treatment without sequelae. All the patients returned to their normal activities and their BMI began to stabilize approximately 2 years following surgery.

**Conclusions** The Santoro III procedure is an attractive option for adolescent BS, with promising 1-year follow-up results. These initial studies should be monitored for long-term outcomes and confirmed on a larger group of patients.

**Keywords** Adolescent · Bariatric surgery · Morbid obesity · Childhood obesity · GLP-1 · Ghrelin

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M. C. P. Velhote (✉)  
Service of Pediatric Surgery,  
São Paulo University Medical School,  
São Paulo, Brazil  
e-mail: mvelhote@uol.com.br

D. Damiani  
Pediatric Endocrinology Unit,  
São Paulo University Medical School,  
São Paulo, Brazil

**Present Address:**  
M. C. P. Velhote  
Instituto da Criança, HC-FMUSP,  
Rua Eneas Carvalho Aguiar 647,  
CEP 05403-000 São Paulo, São Paulo, Brazil

## Introduction

Surgery has been recognized as the only effective therapeutic approach resulting in long-term, persistent weight loss in morbidly obese adults [1]. Several established techniques based on restrictive, malabsorptive, or mixed procedures have been proposed to attain increased weight loss, with encouraging results [2]. However, these techniques require life-long medical surveillance and vitamin and nutrient supplementation, and they are also frequently accompanied by dysphagia and vomiting due to anatomical restrictions, as well as adverse metabolic effects [3].

As a result of limited clinical studies the literature, only recently have adolescents been accepted as suitable patients for bariatric procedures [4, 5]. In the event that an adolescent does receive bariatric surgery (BS), they typically undergo laparoscopic adjustable gastric banding (LAGB) or Roux-en-Y gastric bypass (RYGBP) [6].

Since childhood obesity begins early in life, the results of any weight loss operation must be maintained for a significantly longer time than in adults. Given this fact, perhaps more radical and definitive bariatric operations should be considered for adolescents, especially if medical surveillance could be minimized in the late postoperative period.

Recently, a novel bariatric technique was described that was based on nonrestrictive, nonmalabsorptive procedures. This technique is grounded upon sound physiological concepts, linking the modern obesity epidemic to a hypothetical maladaptation of the human gut to the modern diet [7, 8]. The digestive system, developed over millennia, was originally adapted to the digestion of complex hypocaloric, unprocessed, and scarce food. On the other hand, the modern diet is easily obtained, predigested, and poor in fiber content, and as such is almost completely absorbed in the jejunum. In the case of the modern diet, very few residual nutrients reach the distal small bowel and, hence, the satiety enterohormones GLP-1 and PYY are not properly secreted [9].

In 2003, Santoro [7] proposed a new surgical strategy for extreme obesity that utilizes a novel combination of different pre-existing surgical procedures. The theoretical and physiological basis for this surgical strategy, as well as surgical outcome results, were recently reviewed [10]. The Santoro III technique consists of a laparoscopic sleeve gastrectomy and enteromentectomy, which reduces gastric capacity to about 150 ml and the small bowel length to 3 m, preserving the distal small bowel.

The objective of the omentectomy is to reduce the amount of visceral fat, an excess of which is commonly associated with development of metabolic syndrome [11]. Specifically, the omentectomy helps decrease hepatic insulin resistance by reducing levels of resistin [8] and portal free fatty acids.

The promising initial results with surgery performed with the applications of those principles in adults, now with more than 600 patients operated, stimulated its use in adolescents, and the potential absence of restrictive obstacles to food ingestion and malabsorption, potentially allowing normal life and growth, was a very attractive condition.

The following study presents the outcome of the first ten morbidly obese adolescents to undergo Santoro III surgery. The procedure was performed within the last 4 years by a pediatric surgical team in a pediatric university teaching hospital, and results were obtained at 1-year follow-up.

## Methods

The inclusion criteria for BS candidates followed the 2004 American Society for Bariatric Surgery (ASBS) Consensus Conference guidelines [4]. The criteria included an evaluation by a multidisciplinary team, a body mass index (BMI) over 40 kg/m<sup>2</sup>, and a failure in weight reduction after at least 2 years of clinical treatment.

This study examines the 1-year follow-up of the first ten consecutive adolescents (seven females) to receive the Santoro III technique. The patients were operated by the same surgeon in the Pediatric Surgical Service of São Paulo University Medical School from July 2003 to August 2006. The patients ranged in age from 14 to 19 years (median 16 years) with weight ranging from 124 to 219 kg (average 138.8±33.8 kg). This is the first report of the application of this surgical procedure in adolescents and must be interpreted as a limited, but promising, initial outcome.

All of the patients were morbidly obese, with BMI varying from 44 to 72 kg/m<sup>2</sup> (average 51.7±9.5 kg/m<sup>2</sup>). At the time of operation, three patients had diabetes mellitus type 2, two were insulin resistant and one was hypertensive (Table 1).

All subjects had been obese since childhood and had received at least 2 years of intensive medical weight loss treatment. Of the ten patients, four were formerly admitted for inpatient hospital weight loss treatment without success. For inclusion in the study, the adolescents were all evaluated by a multidisciplinary team that included a pediatric endocrinologist, dietician, physiotherapist, psychologist, and pediatric surgeon.

The patients and their families were informed about surgical options, associated risks, and expected outcomes before an informed consent was signed.

The surgical technique has been previously described [8]; briefly, the procedure consists of a laparoscopic sleeve gastrectomy followed by an open omentectomy and small

**Table 1** Associated comorbidities

Patient	Sex	Comorbidities
NTS	♀	None
ACC	♀	T2DM, hypertension
TS	♂	Impaired GTT
FCO	♀	None
CF	♀	None
JECC	♀	High cholesterol, hyperglycemia, orthopedic disease
BS	♂	T2DM
TCV	♀	None
BC	♂	T2DM
KTS	♀	None

T2DM Type 2 diabetes mellitus; GTT glucose tolerance test

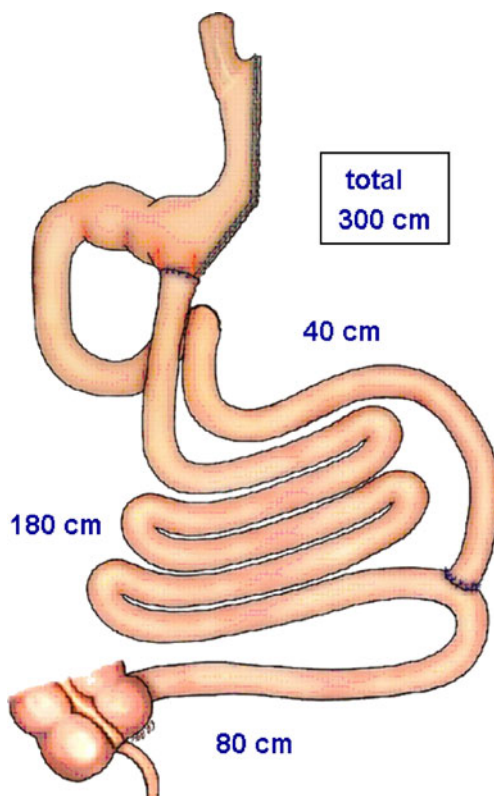
bowel resection to 3 m, retaining 1.20 m of small bowel and duodenum in normal transit and 1.80 m in a Roux-en-Y gastroenteroanastomosis, as demonstrated in Fig. 1.

Antibiotics and deep vein thrombosis prophylaxis were used (single dose of cephazolin 1 g IV preoperatively and enoxaparin 40 mg once daily until discharge from hospital).

Pre- and postoperative laboratory tests included, among others, the following: hemoglobin, albumin, cholesterol (total, HDL, and LDL), triglyceride, glucose, and insulin levels, as well as glycemic and insulinemic curves and calcium, phosphorus, and hepatic enzyme measurements.

The present study was approved by de Ethical Committee for Analyses of Research Projects of the University of São Paulo Medical School (CAPPesq-FMUSP), and an informed consent document was signed by the patient and their parents or guardians following a detailed explanation of the procedure and risks. The pre- and postoperative patients participated in several meetings where they were encouraged to share information about their experiences.

Despite promising results in clinical outcome and weight loss, this study is intended to be a preliminary investigation with the adolescent patient population, and as such, the authors recommend waiting for long-term follow-up before dictating treatment decisions.



**Fig. 1** Schematic of the Santoro III surgery: sleeve gastrectomy with enterointerectomy, leaving 1.20 m of small bowel in normal transit and a 1.80 m nonabsorptive loop via Roux-en-Y gastroenteroanastomosis



**Fig. 2** Radiologic evidence of bipartition of the postoperative digestive transit: contrast through the duodenum and gastroenteroanastomosis

### Rationale for the Surgical Technique

A new discipline known as neurogastroenterology connects the gastric and intestinal motility control and signals involved in the elicitation of hunger, satiety, and aversion [12].

Today, we know that traditional adult bariatric operations succeed not only because of their restrictive or malabsorptive effects but more so because of stimulation of satiogenic enterohormones from L-cells of the distal bowel, specifically GLP-1 and PYY [13]. GLP-1 and PYY signals to the hypothalamus to communicate satiety, and GLP-1, as an additional benefit, is also an incretin, which is the most powerful physiological stimulant for insulin secretion and promotes an increase in the number of pancreatic  $\beta$ -cells in the islets of Langerhans [14].

The Santoro strategy includes a small restrictive action reducing the gastric capacity and decreasing ghrelin production, but its main goal is to promote arrival of nutrients into the distal small bowel to stimulate the secretion of enterohormones such as GLP-1 and PYY. Rerouting nutrients to the distal small bowel is obtained through the innovative approach of an enterectomy and reconstruction with gastric transit bipartition and Roux-en-Y anastomosis. An increase in postoperative levels of GLP-1 and PYY has already been clearly demonstrated [8, 10]. This surgery is performed without creation of extremely small gastric pouches, prosthesis, blind loops, or duodenal exclusion. It maintains, at least in part, gastric digestion, pyloric function and all duodenal, jejunal and ileal physiology without any degree of clinically detectable caloric or nutrient malabsorption.

Radiologic studies were routinely performed postoperatively and revealed evidence of digestive transit bipartition

**Table 2** Weight losses and BMI changes—1 year postoperative

	Age	Weight at surgery	1 year weight	Weight loss	BMI at surgery	1 year BMI	BMI decrease
NTS	17	129	104	25	59	47	12
ACC	16	135	73	62	55	29	26
TS	17	219	134	85	72	44	28
FCO	19	139	80	59	49	28	21
CF	14	124	82	42	47	31	16
JECC	14	107	69	38	43	28	15
BS	15	145	87	58	53	32	21
TCV	17	124	80	44	44	28	16
BC	15	140	93	47	51	34	17
KTS	19	126	77	42	44	27	15
Mean	16.3	138.8	87.9	50.9	51.7	32.8	18.9

BMI in kg/m<sup>2</sup>; Weight in kg; Age in years

with equivalent amounts of contrast moving toward the duodenum and gastroenteroanastomosis (Fig. 2). None of these patients developed signs or endoscopic evidence of marginal ulcers in the gastroenteroanastomosis.

## Results

There were no intraoperative complications. Nasogastric tubes were not used, and oral feeding was reinstated 24 h postoperatively with small amounts of liquid and jelly every 2 h. With the exception of the patient who developed an intraperitoneal abscess, the mean postoperative hospital stay was 3 days.

All the patients were followed for at least 1 year (range 1 to 4 years). They all demonstrated consistent and satisfactory weight loss and reduction in BMI. After 1 year, the mean weight loss was 51.7±21.1 kg and the percent of excess of BMI lost (%EBL) was 83.9%, as shown in Table 2.

There were no deaths during this study. Early complications were minimal: one patient developed an intrabdominal abscess without digestive fistula and completely recovered following drainage; another patient had a small skin

dehiscence that was successfully resutured under local anesthesia.

Table 3 shows pre- and postoperative laboratory test results.

One year after the surgery, all patients demonstrated significant decreases in blood glucose, insulin, triglyceride, and total and LDL-cholesterol levels, with a marginal increase in HDL-cholesterol. Albumin and hemoglobin levels remained unchanged.

In regards to late complications, one patient was suspected to have thiamine deficiency, with paresthesias and pain in the lower limbs during the rapid weight loss phase, without diarrhea or vomiting. These symptoms disappeared, without sequelae, following administration of oral vitamin B1.

Three patients with normal preoperative abdominal ultrasounds, developed symptomatic cholelithiasis and underwent routine laparoscopic cholecystectomies without complication.

All the patients were able to eat without difficulty and have normal bowel movements, with no detection of dumping, steatorrhea or flatulence. All medications were suspended after 1 year of follow-up. Postoperative psychological evaluations revealed significant improvement in

**Table 3** Preoperative and postoperative laboratory test

	Preoperation	Postoperation	<i>p</i> value
Glycemia (mg/dl)	106.0±29.7	80.4±69.78	0.044*
Insulinemia (μU/ml)	33.0±35.7	4.71±7.30	0.043*
Cholesterol (mg/dl)	179.13±32.30	135.00±33.64	0.020*
LDL-cholesterol (mg/dl)	112.75±28.29	84.00±35.09	0.026*
HDL-cholesterol (mg/dl)	39.5±4.69	46.63±10.46	0.086
Triglycerides (mg/dl)	104.13±43.89	69.63±36.39	0.026*
Albumin (g/dl)	4.29±0.26	4.25±0.27	0.348
Hemoglobin (g/dl)	13.15±1.50	13.54±1.65	0.671

Paired *t* test - \* *p*<0.05

self-esteem and timely return to school, social or working activities. All patients continue their weight loss, although at a slower pace, until 2 years following their operation.

Patient adherence to recommended physical activities was only partially successful.

## Discussion

Currently, the only effective treatment for extreme obesity in adults is bariatric surgery [1]. Recently, bariatric surgery has also been recognized as an appropriate treatment for morbid obesity in adolescents [15, 16]. Currently, adolescent surgery accounts for only 0.73% of all bariatric procedures in the USA [17], but as this treatment becomes more accepted, this number is certain to increase in the upcoming years [18]. Modern bariatric surgical techniques are restrictive procedures, creating blind and inaccessible gastrointestinal loops and frequently utilizing prosthetic material. These techniques require frequent long-term medical follow-up and have additional complications such as dental problems, bone disease, and vitamin deficiency [3, 19].

In 2004, the ASBS Consensus Conference concluded that new surgical approaches should be pursued in order to improve upon currently accepted techniques [4].

The Santoro technique could conceivably be one of these new surgical propositions. Unlike standard bariatric procedures, the Santoro strategy is based on the hypothesis that obesity is, in part, due to the fact that the modern diet is mostly absorbed in the proximal gut, leaving no nutrients to stimulate L-cells of the distal bowel. Stimulation of L-cells is necessary to increase secretion of the satiogenic enterohormones GLP-1 and PYY.

Consequently, adaptive gut remodeling produced by the surgery decreases stomach capacity and small bowel length, removing the more rapidly absorptive portion, the jejunum.

More than 600 adult patients have undergone this surgical strategy, with outcomes revealing effective and maintained weight loss, reversal of metabolic syndrome, and improved quality of life without malabsorption [8, 10].

Our initial experience with adolescents confirms that the Santoro III surgery is especially suitable for and well tolerated by morbidly obese young patients.

We analyzed the outcome of the Santoro III surgery in the first 10 adolescents who had at least 1 year of follow-up. The mean weight loss (50.9 kg) and decrease in BMI (18.9 kg/m<sup>2</sup>, reduction of 37%) with a %EBL of 83.9% in only 1 year following surgery were excellent and at the very least, comparable to results of RYGBP while being superior to those of LAGB.

Excluded in the study were six patients with BMIs over 50 kg/m<sup>2</sup>, who underwent only a sleeve gastrectomy as a

first-step procedure. As recently demonstrated in the literature, an isolated sleeve gastrectomy may be a promising single procedure for surgical treatment of mild and extreme obesities, but studies examining this procedure in adolescents have not yet been performed [20].

In a multicenter study, Lawson et al. [21] reported that 39 adolescents with an initial BMI of 50.2 kg/m<sup>2</sup> who were subjected to RYGBP with 1 year follow-up had a final BMI of 35.8 kg/m<sup>2</sup> (reduction of 37%), with one fatality and seven complications. The reduction in BMI at 1 year post-operative was similar to that seen in our study (37%), but with a higher index of complications.

Angrisani et al. [22] performed a multicenter study with 58 adolescents who underwent LAGB with 1- and 5-year follow-up and demonstrated a reduction in BMI to 35.9 and 34.9 kg/m<sup>2</sup>, respectively. They reported six cases with complications and another six with reoperations. In our study, BMI at the 1-year follow-up was 32.8 kg/m<sup>2</sup>, with fewer complications and no reoperations or weight regain.

RYGBP is a very efficient procedure for reducing the metabolic syndrome [15] and, to a lesser extent, LAGB also attenuates this condition [21]. The Santoro III surgery also resulted in receding metabolic syndrome in adolescents with type 2 diabetes, insulin resistance, and arterial hypertension; at the time of publication, these patients no longer required medications for these diseases.

The Santoro III technique also produced significant decreases in total cholesterol, LDL-cholesterol, triglyceride, glucose, and insulin levels ( $p < 0.05$ ), as shown in Table 3. HDL-cholesterol did not increase significantly ( $p = 0.086$ ), and albumin and hemoglobin levels showed no change during the period of the study.

After the surgery, glucose tolerance testing revealed normal glucose–insulin ratios at all sample points.

One case of clinical beri-beri (lower limb neuritis) with complete regression following thiamine treatment occurred and was attributed not to malabsorption but instead to a low preoperative pool of vitamin B1 [23] and insufficient nutrient intake in the postoperative period. This complication had already been described after RYGB in three adolescents [24].

One important negative consequence of morbid obesity in adolescents is social isolation, depression, and abnormal social behavior [25]. One year postoperatively, as determined by the psychological evaluation team, these symptoms, when initially present, were reversed, with all patients returning to school, social, or work activities.

Despite criticism of this technique [26], specially directed to evolutionary aspects of its basis as well as to the potential risks and unconventional aspects of the partial small bowel resection, there is no evidence in mid-term follow-up of steatorrhea, malabsorption of caloric or noncaloric nutrients such as iron, folic acid, and calcium,

dumping, marginal ulcers, or flatulence. There is also no need for nutritional support or medication except for vitamin supplements during the rapid weight loss phase. Postoperatively, patients show a sustained rise in GLP-1 and PYY levels and a decrease in ghrelin [8], explaining their satiety and continued weight loss without feeding impairment.

In conclusion, the Santoro III surgery is an attractive surgical option for morbidly obese adolescents because it is well tolerated, neither restrictive nor malabsorptive, does not exclude gastrointestinal segments, corrects postprandial secretion of satiogenic enterohormones, deals well with associated comorbidities, and reverses the metabolic syndrome.

One-year postoperative follow-up results suggest that the decrease in weight and BMI was greater for the Santoro procedure as compared to RYGBP and LAGB, with less morbidity and reoperations. In the short term, these patients maintain a sustained and significant weight loss without complaints of vomiting, dumping, diarrhea, flatulence, or dysphagia. As with all other surgical procedures in adolescents, a larger study series with long-term follow-up will be necessary to validate the results suggested by the Santoro III study, which at this time remain primarily academic for adolescents.

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