Biliopancreatic diversion with duodenal switch in the elderly: Long-term results of a matched-control study

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ABSTRACT

Introduction: BPD-DS is one of the most effective surgical approaches for the treatment of severe obesity. **Objective:** To compare perioperative complications and long-term results of open BPD-DS in elderly versus younger patients. **Methods**: All patients aged 60 years and above who underwent a primary open BPD-DS in our center were selected (n=105). Patients were matched 1:1 for sex, BMI, the presence of Type 2 diabetes (T2DM) and year of surgery with a group of younger patients (aged ≤55 years). **Results:** The mean age of the patients was 62.3±2.0 vs. 40.4±7.0 years (p≤0.0001). Initial BMI and prevalence of T2DM were similar in both groups, at 50.9 kg/m^2 and 57%, respectively. Mean operative time (178.6±46.7 vs. 162.5±39.9 min., p=0.01), hospital stay (10.2±8.3 vs. 6.3±1.5 days, p=0.0001) and blood loss (593±484 vs. 474±241ml, p=0.05) were significantly higher in elderly patients. No difference in 30-days mortality rate was observed (0.9% in each group). There was no significant difference in major complication rate (16.2% vs. 8.6%, p=0.09). At a mean follow-up of 7.1±4.1 years, excess weight loss (67.6±19.2% vs. 72.7±20.7%, p=0.06) and BMI (32.2±5.7kg/m^2 vs. 30.8±6.6kg/m^2, p=0.15) were not significantly different. No significant difference was observed between the two groups for the resolution of T2DM (p=0.53) and obstructive sleep apnea (p=0.44). **Conclusion:** Open BPD-DS is associated with similar long-term benefits in elderly and younger patients, in terms of weight loss and resolution or improvement of obesity-related comorbidities. Perioperative complications might be more frequent in the elderly population, but this was not associated with increased mortality.

Keywords: Bariatric surgery, Biliopancreatic diversion, Duodenal switch, long-term results, Elderly

INTRODUCTION

Epidemiological studies demonstrated that obesity rates have progressively increased over the past decades [1-4]. More specifically, the prevalence of severe obesity increased by 225% in Canada (0.4% in 1990 to 1.3% in 2003) [1]. Bariatric surgery is still the only treatment for severe obesity to offer significant and durable weight loss [5]. Biliopancreatic diversion with duodenal switch (BPD-DS) is one of the most effective surgical approaches for the treatment of severe obesity in terms of weight loss and resolution of comorbidities [6, 7]. BPD-DS was developed at the Quebec Heart and Lung Institute (IUCPQ) in the early 1990s and became the primary approach for most severely obese patients. This procedure combines restrictive and malabsorptive mechanisms by creating a 250-cm^3 sleeve gastrectomy (SG), while the duodenum is transected about 4 cm distal to the pylorus and anastomosed to a 250-cm alimentary limb, with a 100-cm common channel [6, 8].

The effect and long-term outcomes of bariatric surgery procedures in various sub-populations of severely obese patients have been reported extensively in the past years [5, 6, 8-15]. However, the risks and benefits of these operations in elderly patients are still debated [16-18]. Indeed, multiple studies [19-37], two recent reviews [16, 18] and one meta-analysis [17] have examined this question and no consensus could be reached. One review concluded that bariatric surgery is safe and effective in elderly patients [16], while the other concluded that bariatric surgery in this population is associated with higher perioperative complications, and lower weight loss and comorbidities resolution [18]. Of the studies available, most were retrospective, and included small patient numbers and

no control group [17]. Furthermore, long-term data in the elderly population are still very limited and very few studies are available regarding the effectiveness of BPD-DS specifically in elderly patients [17].

Considering that the prevalence of severe obesity increased [1] and that the population is ageing [18], more data are needed on the safety and effectiveness of BPD-DS in elderly patients. Our objective was to compare perioperative complications and long-term results of open BPD-DS in elderly versus younger patients. We tested the hypothesis that open BPD-DS is associated with similar long-term benefits in elderly compared to younger patients, in terms of excess weight loss and resolution of obesity-related comorbidities.

RESEARCH DESIGN AND METHODS

Patients

The present study took place at a single university-affiliated tertiary care center. All patients aged 60 years and above who underwent a primary open BPD-DS with standard intestinal measures (250-cm alimentary limb and 100-cm common channel) from November 1992 to September 2011 were included in the study (n=105). These patients were individually matched (1:1) for sex, BMI, the presence of T2DM and the year of surgery with a group of younger patients (aged ≤55 years, n=105). Data were obtained from a prospectively maintained database. The database and the medical record were reviewed for each patient. In the present study, preoperative data obtained for each patient included age, gender, weight, height, body mass index (BMI), comorbidities and medication use. The indications for surgery followed the National Institutes of Health guidelines [38], except for age in the elderly subgroup. The decision regarding surgery was made in collaboration with the bariatric multidisciplinary team (surgeon, nutritionist, social worker and bariatric nurse) and the patient. All patients were informed about the risk and benefits of the BPD-DS and they participated in a support group before surgery. This study received approval from the Ethics Committee of our institution.

Surgical technique

Patients received intravenous antibiotics and subcutaneous heparin 2 hours before surgery. Pneumatic compression devices were used during surgery and until ambulation. The surgical technique consisted in open BPD-DS with a 250-cm alimentary limb and a 100-cm common channel, as previously described [6]. Sleeve gastrectomy starting 7 cm

proximal to the pylorus was performed using a 52F bougie for calibration. Routine cholecystectomy and appendectomy were performed.

Perioperative period, follow-up and outcome definitions

Regular subcutaneous heparin was given for the first postoperative day and then switched to low-molecular-weight heparin. Patients were discharged with the same regimen for 3 weeks when they were tolerating a soft diet. Vitamin and mineral supplementation (ferrous sulfate 300mg, vitamin D 50 000IU, vitamin A 20 000IU, calcium carbonate 500-1000mg, and a multivitamin complex) were started within the first month after surgery and these supplements were adjusted during follow-up according to plasma nutritional markers. Nutritional deficiencies were immediately corrected using standardized protocols. Patients also received recommendations to consume a high-protein diet. Perioperative data such as operative time, duration of hospital stay, blood loss, mortality rate as well as major and minor complications within 30 and 90 days postoperatively were recorded. The hospital stay was defined as the number of days from operation to hospital discharge. The reoperation rate within 10 days was also calculated.

Follow-up data were gathered at 3, 6, 9 and 12 months postoperatively and yearly thereafter. Clinical biochemistry values included a complete blood count, liver enzymes, albumin, transferrin, iron, ferritin, calcium, parathyroid hormone, vitamin A, vitamin B12 and folic acid. Bariatric nurses remained in contact with these patients and their primary care physician, making a yearly average of 6 phone calls per patient [6]. Information regarding late complications and hospitalizations were documented in the database. To

verify the collected information, an auto-administered written questionnaire was sent to each patient every 5 years. These questionnaires included questions regarding overall and weight loss satisfaction, quality of life, side-effects, complications and evolution of comorbidities. To evaluate the nutritional condition of the two groups, we compared nutritional laboratory values after 5 years of follow-up with those obtained prior to surgery. Percentage of excess weight loss (%EWL), postoperative BMI and percentage of total weight loss (%TWL) after a mean follow-up of 7.1±4.1 years were calculated for all patients. The %EWL was calculated using these variables: total preoperative weight, postoperative weight and ideal body weight (IBW) for an ideal BMI of 23kg/m^2 as previously used [8]. Resolution of comorbidities (T2DM, hypertension and sleep apnea) was also recorded. The resolution or improvement of T2DM, hypertension and sleep apnea was evaluated by surgeons during follow-up on the basis of clinical parameters, laboratory data and the reduction or discontinuation of medical therapy. The resolution of T2DM was defined as a normal glycosylated hemoglobin (HbA1c) (<6%) or normal fasting blood glucose (<5.6mmol/L) and absence of anti-diabetic medication use. The resolution of hypertension was defined as normal resting systolic and diastolic blood pressure (BP<120/80 mm Hg) as well as absence of anti-hypertensive medication use. The resolution of sleep apnea was defined as cessation of the use of continuous positive airway pressure (CPAP). T2DM, hypertension and sleep apnea were improved when patients had improved clinical parameters and/or medication dose was decreased.

Statistical analysis

Student's t-tests were performed to compare continuous variables between patients aged 60 years or older and controls (patients aged ≤55 years). Chi-square tests or Fisher's exact tests were performed to compare categorical variables, as appropriate. Repeated-measures analysis of variance was used to examine the effect of group (elderly patients (age ≤ 55 years) versus younger patients (age ≥ 60 years)) and time (before-BPD-DS and 5 years post-BPD-DS) as well as the time-by-group interaction for mean levels of albumin, calcium, hemoglobin and iron. Non-normally distributed variables were log- or boxcox-transformed. When variables could not be normalized, Wilcoxon tests were computed to compare continuous variables. Results are reported as mean ± standard deviation for continuous variables or percentage for categorical variables comparing elderly to younger patients. The results were considered statistically significant with p values ≤ 0.05. All statistical analyses were performed with JMP software (SAS Institute Inc, Cary, NC, U.S.A.).

RESULTS

Preoperative characteristics

Preoperative demographic characteristics of the two groups are shown in **Table 1**. The mean age of the patients at the time of surgery was 62.3±2.0 versus 40.4±7.0 years ($p \leq 0.0001$). As expected from our matching procedure, preoperative BMI, gender and % of T2DM were similar in both groups. In the elderly group, 36.7% (n=22) of diabetic patients were on insulin treatment compared to 20% (n=12) in the younger group (p=0.04) (data not shown). Hypertension, cardiovascular disease, dyslipidemia and obstructive sleep apnea affected 72%, 20%, 38% and 64% of all patients respectively. Patients aged 60 years and above had a significantly higher mean number of comorbidities (p=0.002) and used a significantly higher mean number of preoperative daily medications (5.4±2.9 versus 3.9±3.4, p=0.0001, data not shown) compared to younger patients.

Perioperative data, early mortality and early complications (≤ 30 days)

Including all patients, mean postoperative hospital stay was 8.2±6.1 days and mean operative time was 170.5±44.1 minutes (**Table 2**). Mean operative time, hospital stay and blood loss were all slightly but significantly higher in the elderly group ($p \leq 0.05$, for all). The rate of reoperation during the first 10 postoperative days was similar between the two groups. One death (0.9%) occurred within 30 days in each group (a 30-year-old patient died from a pulmonary embolism 12 days after surgery and a 70-year-old patient died from multiple organ failure. At 90-days, mortality was 0.9% (1/105) in the younger group versus 1.9% (2/105) in the elderly group (p=0.55).

Major complications in first 30 postoperative days are shown in **Table 3**. Major complications occurred in 12.4% of all patients. A trend was observed for an increased rate in total major 30-days complications in elderly patients compared to younger ones (16.2% versus 8.6%, p=0.09). The rate of digestive leak, abdominal abscess, pancreatitis, pneumonia, hemorrhage, pulmonary embolism, intestinal obstruction and stenosis was similar between the two groups. **Table 4** shows minor complications in first 30 postoperative days. There was no significant difference between the two groups for total minor complication rate (13.3% versus 9.5%, p=0.40).

Long-term results: weight loss, general satisfaction, resolution of comorbidities, complications, nutritional outcomes and long-term mortality

The mean follow-up time was similar between the two groups (7.2±4.2 years in the elderly group versus 7.1±4.1 years in the younger group, p=0.89). The percentage of follow-up was 97% in elderly patients (102/105) and 99% in younger patients (104/105). **Figure 1A** shows mean percentage of initial excess weight loss (%EWL) for the two groups after 6, 12, 24, 36, 48 and 60 months of follow-up. The mean %EWL was significantly higher in younger patients after 6, 12, 24, 36 and 48 months of follow-up ($p \leq 0.05$ for all, **Figure 1A**). However, the difference in %EWL between the two groups was not significant after 60 months of follow-up (p=0.22). In both groups, weight loss remained relatively stable over the years (**Figure 1A**). After a mean follow-up of 7.1±4.1 years, there was no significant difference between the two groups for %EWL (67.6±19.2% versus 72.7±20.7%, p=0.06) and BMI (32.2±5.7kg/m^2 versus

30.8±6.6kg/m^2, p=0.15) (**Figure 1B and D**). The %TWL was significantly higher in younger compared to elderly patients (p=0.05) (**Figure 1C**). The percentage of successful weight loss which is defined as an average weight loss >50% of initial excess weight was similar in both groups (82.9% in elderly patients versus 85.7% in younger patients, p=0.58, data not shown). After a mean follow-up of 7.1 years, 0.9% (1/105) of elderly patients and 2.9% (3/105) of younger patients had lost less than 25% of their initial excess weight (p=0.37, data not shown). To evaluate overall satisfaction of patients regarding surgery and weight loss, an auto-administered questionnaire was sent in 2011. Of the 210 patients, 108 patients (51%) correctly filled the questionnaire. According to this questionnaire, 85.7% (54/63) of the elderly group were satisfied (score 4 or 5 on a 1 to 5 Likert-scale) with their weight loss compared to 97.8% (45/46) of the younger group (p=0.10) (data not shown). Only 2 older patients (3.2%) were unsatisfied (score 1) with their weight loss. In both groups, no revision surgery was required for insufficient weight loss.

The questionnaire also included questions regarding frequency of stools, prevalence of diarrhea, bloating and flatulence/odor problems. The mean number of stools per day was 2.8±1.5 in elderly patients and 3.2±1.6 in younger patients (p=0.17) (data not shown). The number of stools per day was not considered as a significant problem in most of the elderly (92%) as well as younger (95%) patients. The presence of abdominal bloating (more than once a week) was found in 39% of the elderly group compared to 44% of the younger group (p=0.50) (data not shown). Flatulence or odors were considered as a major problem in 30% of the elderly group and in 33% of the younger group (p=0.67) (data not

shown). In both groups, no reoperation was specifically performed to address number of stools per day or frequency of flatulence/odor problems.

Figure 2 shows the resolution of obesity-related comorbidities among younger and elderly patients after a mean follow-up of 7.1±4.1 years. No significant difference was observed between the two groups for the resolution of T2DM (p=0.53) (**Figure 2A**). In the elderly group, T2DM was cured in 83.3% (50/60), improved in 8.3% (5/60) and unchanged in 1.7% (1/60). In the younger group, T2DM was resolved in 91.7% (55/60), improved in 3.3% (2/60) and unchanged in 1.7% (1/60). In both groups, a significant decrease in HbA1c was observed at the last follow-up (the most recent postoperative value) compared to levels obtained prior to surgery (Elderly patients: 6.8±1.2% versus 5.2±0.7%, p<0.0001, n=48; Younger patients: 6.8±1.9% versus 5.0±0.6%, p<0.0001, n=43) (data not shown). A significant difference between the younger and elderly groups was observed for hypertension resolution (**Figure 2B**). Indeed, hypertension was resolved in 41.1% (35/85), improved in 41.1% (35/85) and unchanged in 7.1% (6/85) in the older group compared to 66.7% (44/66), 13.6% (9/66) and 13.6% (9/66) respectively in the younger group (p=0.008). The resolution of obstructive sleep apnea was similar between the two groups (p=0.44) (**Figure 2C**). Sleep apnea was resolved in 72.9% (43/59) and improved in 10.2% (6/59) in younger patients compared to 77.3% (58/75) and 12.0% (9/75) respectively in elderly patients. Of the 75 older patients treated for sleep apnea before BPD-DS, only 2 patients (2.7%) required treatment after surgery.

Changes in nutritional parameters

To evaluate the nutritional condition of the two groups, we compared nutritional markers after 5 years of follow-up with those obtained prior to surgery, when both were available (**Figure 3**). No significant difference was observed between the two groups for mean level of albumin measured prior to and 5 years after BPD-DS (Group effect, p=0.79) (**Figure 3A**). In both groups, mean albumin level was slightly decreased after 5 years of follow-up compared to that obtained prior to surgery (Time effect, p=0.02). Taking into consideration the most recent postoperative albumin level, most patients remained within the normal limit (albumin level >35g/L). Only 18.1% of elderly patients and 5.7% of younger patients were below normal (albumin level ≥30 but <34.9g/L). The percentage of severe hypoalbuminemia (<30 g/L) was very low and similar in both groups prior to surgery and at the last follow-up (most recent nutritional markers obtained after the surgery) [Elderly patients: 0.9% (preoperatively) versus 0% (postoperatively), n=105; Younger patients: 0% (preoperatively) versus 0.9% (postoperatively), n=105] (data not shown). **Figure 3B** shows that elderly patients had higher level of calcium prior to and 5 years after BDP-DS compared to younger patients (Group effect, p=0.03). In both groups, mean level of calcium was significantly decreased 5 years after BPD-DS compared to mean level obtained pre-BPD-DS (Time effect, p=0.0001). Parathyroid hormone level was significantly increased in each group 5 years after BPD-DS (Time effect, p=0.0001) (data not shown). Severe calcium deficiency (<2g/L) at last follow-up was low in both groups (2.9% in elderly versus 1.9% in younger patients). Hemoglobin level was lower 5 years after surgery than before in both groups (Time effect, p=0.0001) (**Figure 3C**). However, in both groups, no significant decrease in iron levels was observed after 5 years

of follow-up (**Figure 3D**) and an increase in folic acid and vitamin B12 levels was observed postoperatively (data not shown). The percentage of patients with hemoglobin value lower than 100g/L was very low and similar in both groups prior to and at the last follow-up (0% preoperatively versus 0.9% postoperatively in both groups (data not shown). There was no significant difference between the two groups for levels of hemoglobin and iron before and 5 years after BPD-DS (**Figure 3C and D**).

Table 5 shows causes of late hospitalization related to bariatric surgery during follow-up. Including all patients, the main cause for rehospitalisation was malnutrition (8.1%). The percentage of rehospitalisation for malnutrition tended to be higher in elderly patients compared to younger ones (p=0.08). However, in both groups, the majority of patients required only medical treatment. Surgery for malnutrition was required in 3 elderly patients and in 1 patient of the younger group (p=0.27). Lengthening of the common channel (typically from 100 to 200 cm along the biliary limb) was successful in all patients. The percentage of late hospitalization for delayed fistula, stenosis, incisional hernia, gastrointestinal bleeding, intestinal obstruction, diarrhea, abdominal pain, pulmonary embolism, pancreatitis and abscess was similar between the two groups (**Table 5**). Surgery for intestinal obstruction was significantly higher in younger patients compared to older ones (7.6% versus 0.9%, p=0.02).

After a mean follow-up of 7.1 years (range: 6 months to 19 years), 9 (8.6%) long-term deaths in the elderly group were reported compared to 2 (1.9%) in younger patients (p=0.03) (data not shown). In the elderly group, 2 died from cancer, 1 from trauma, 1

315 from pulmonary disease, 2 from cardiac causes and 1 from ulcerative colitis. In this
316 group, two deaths were related to bariatric surgery (1 from intra-abdominal abscess and 1
317 from gastric fistula). In the younger group, 1 patient died from lung cancer and 1 patient
318 died from pulmonary problem (severe asthma). No significant difference was found
319 between the two groups for long-term deaths related to BPD-DS ($p=0.20$).
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DISCUSSION

To our knowledge, this is the first study to clearly compare perioperative complications and long-term results of open BPD-DS in elderly patients versus a matched control group of younger patients. We tested the hypothesis that open BPD-DS is associated with similar long-term benefits in elderly and younger patients, in terms of excess weight loss and resolution of obesity-related comorbidities. We found that mean operative time, hospital stay and blood loss were all slightly but significantly higher in the elderly group. However, 30-day mortality rate was similar in both groups (0.9%, in each group) and in acceptable ranges for open surgery performed an average 7 years ago. We found a trend for an increased rate of major 30-days complications in the elderly group. Regarding long-term results, we demonstrated that in both groups, weight loss remained relatively stable over the years. After a mean follow-up of 7.1 years, there was no significant difference between the two groups for %EWL, BMI and % of success IEW. Furthermore, most of the patients in both groups had a marked improvement or resolution of their obesity-related comorbidities.

One important finding in the present study is that our results showed significant and durable long-term weight-loss after BPD-DS in both younger and older patients, with a mean %EWL of 73% and 68% respectively. Consistent with our results, Buchwald et al. [10] reported in a meta-analysis that BPD-DS resulted in the greatest long-term %EWL (70.1%) compared to others surgeries. In both groups, we found that most of the patients had a successful long-term weight loss (>50%IEW). Furthermore, no revision surgery was performed for insufficient weight loss. Previous studies also reported clinically

significant excess weight loss and improvement in quality of life after bariatric surgery in elderly patients, but most of these effects were not as significant as those observed in younger patients [16, 26, 28, 37, 39]. However, most of these studies have only examined short-term weight-loss (< 1 year of follow-up after surgery). In the present study, we also reported that %EWL was significantly lower in elderly patients after 1 year of follow-up. Nevertheless, these differences were not statistically significant after a mean follow-up of 7.1 years, suggesting that open BPD-DS results in substantial long-term weight-loss in both younger and older patients.

Our study also demonstrated that most of the patients in both groups had a marked improvement or resolution of their obesity-related comorbidities. Even if the complete resolution of hypertension was higher in younger patients compared to older ones, we found that improvement of hypertension was clinically significant in both groups. The resolution of type 2 diabetes and sleep apnea was similar in both groups. Consistent with our results, a meta-analysis by Buchwald et al. [9] reported that T2DM was improved or resolved in 86.6% after bariatric surgery. According to a more recent meta-analysis, T2DM resolution after BPD-DS was 89%, which is also comparable to our results [40]. Leivonen et al. [23] demonstrated that the resolution of T2DM and hypertension was similar between older and younger patients after 12 months post SG. Interestingly, Lynch and Belgaumkar [17] also reported in a meta-analysis of 18 studies that the resolution of hypertension, diabetes, sleep apnea and lipid abnormalities was similar to those observed in younger patients.

Even if BPD-DS seems to be associated with higher perioperative risks and mortality rate compared to others surgeries [41, 42], the 30-day mortality rate in our study was low and similar to that of other bariatric surgery procedures performed by open surgery and in similar periods (0-4.3%) [43]. Interestingly, we found no significant difference in early mortality rate between the two groups (0.9%, in each group). In contrast to our results, Flum et al. [25] previously reported that the early mortality rate after RYGB was significantly higher in elderly (≥65 years) compared to younger patients. In a cohort obtained from the American College of Surgeons National Surgical Quality Improvement Program database, Dorman et al. [24] demonstrated that older age tended to predict mortality, but this was not statistically significant. Consistent with our results, Dunkle-Blatter et al. [26] reported no significant difference between older and younger patients for 30-day and 90-day operative mortality rates. Considering that mortality rate may be influenced by several factors such as the type of procedure, the volume of bariatric surgery, the improvement of surgical management, the optimization of perioperative care and the anesthesia [17, 43, 44], the comparison of mortality rate between studies remains challenging. However, in our matched-control study, we reported no significant difference in short-term or long-term mortality rate related to BPD-DS between younger and older patients.

Furthermore, our study demonstrated that elderly patients tented to have higher 30-day major complication rates. Even if our two groups were individually matched for gender, BMI, the presence of T2DM and year of surgery, it is important to take into consideration that elderly patients had a significantly higher number of pre-operative comorbidities and

used a higher number of daily medications. As reported by others [16, 26, 28, 29, 43, 45], elderly patients are often a "higher-risk" group of patients with higher perioperative comorbidities. This could explain why we observed a trend for higher 30-day major complications and a significantly longer hospital stay. Dorman et al. [24] previously reported that elderly age (≥65 years) was an important risk factor for short-term prolonged hospital stay but it was not a significant predictor for major adverse events.

As previously reported [6, 8, 46], the risk of BPD-DS in terms of late malnutrition and nutritional deficiencies is real but with appropriate long-term follow-up of patients as well as standardized vitamin and mineral supplementation, the risk is relatively low. The present study demonstrated that after a mean 7.2 years of follow-up, the percentage of severe hypoalbuminemia was low and similar in both groups. Mean level of albumin and hemoglobin were slightly decreased after 5 years of follow-up in both groups. However, we found that elderly patients tended to have higher rehospitalisation rates for malnutrition. Our results suggest that long-term postoperative care remains essential in both groups, especially in older ones. Rigorous nutritional monitoring may improve management of potential deficiencies in all patients.

Limits of the study should be acknowledged. Considering that laparoscopic BPD-DS has been introduced in 2006 in our institution and that one of the primary endpoints of the study was to examine long-term outcomes of BPD-DS, patients who underwent laparoscopic BPD-DS with standard intestinal limb lengths were excluded from the study. Several studies recently demonstrated the enhanced safety of laparoscopic bariatric

surgeries compared to open surgeries. Indeed, laparoscopic approaches seem to be related to better outcomes in terms of mortality rate, length of stay and complications [43]. Most importantly, we previously reported lower 30-day mortality rates, blood loss and shorter hospital stays with laparoscopic BPD-DS [11], suggesting that the laparoscopic approach may be beneficial in both younger and older patients. Another acknowledged limitation of the study is that even if the data were collected prospectively, this study is still retrospective. Furthermore, some data were missing and some of the information regarding surgery and weight loss satisfaction were from a self-administered questionnaire. Nevertheless, one of the major strength of our study is that we reported long-term results of BPD-DS, using a matched-control group. Such studies are very scarce in the literature. We also examined a rather large sample of patients for which we also had detailed data on weight loss, comorbidities resolution, complications, short and long-term mortality rates and nutritional parameters.

In conclusion, our study suggests that open BPD-DS is associated with similar favorable long-term benefits in elderly and younger patients, in terms of weight loss and resolution or improvement of obesity-related comorbidities. As expected, rates of perioperative complications tend to be higher in the elderly population but this was not associated with increased mortality.

GRANT

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CONFLICT OF INTEREST STATEMENT

A. Tchernof and L. Biertho are co-directors of a Research chair in bariatric and metabolic surgery. A. Michaud, G. B. Marchand, M. Nadeau, S. Lebel, FS. Hould, S. Marceau, O. Lescelleur, S. Biron, A. Tchernof and L. Biertho have no financial relationships relevant to this manuscript to disclose.

ETHICAL APPROVAL

For this type of study formal consent is not required. This study received approval from the Ethics Committee of our institution.

INFORMED CONSENT

Does not apply.

REFERENCES

1. Katzmarzyk PT, Mason C. Prevalence of class I, II and III obesity in Canada. CMAJ. 2006;174(2):156-7.
2. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. JAMA. 2010;%20;303(3):235-41.
3. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960-1994. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 1998;22(1):39-47. PMID: 9481598.
4. Seidell JC, Flegal KM. Assessing obesity: classification and epidemiology. British medical bulletin. 1997;53(2):238-52. PMID: 9246834.
5. Elder KA, Wolfe BM. Bariatric surgery: a review of procedures and outcomes. Gastroenterology. 2007;132(6):2253-71.
6. Marceau P, Biron S, Hould FS, Lebel S, Marceau S, Lescelleur O, et al. Duodenal switch: long-term results. ObesSurg. 2007;17(11):1421-30.
7. Prachand VN, Davee RT, Alverdy JC. Duodenal switch provides superior weight loss in the super-obese (BMI > or =50 kg/m2) compared with gastric bypass. Annals of surgery. 2006;244(4):611-9. PMID: 16998370.
8. Biertho L, Biron S, Hould FS, Lebel S, Marceau S, Marceau P. Is biliopancreatic diversion with duodenal switch indicated for patients with body mass index <50 kg/m2? SurgObesRelat Dis. 2010;6(5):508-14.
9. Buchwald H, Estok R, Fahrbach K, Banel D, Jensen MD, Pories WJ, et al. Weight and type 2 diabetes after bariatric surgery: systematic review and meta-analysis. The American journal of medicine. 2009;122(3):248-56 e5. PMID: 19272486.
10. Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrbach K, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004;292(14):1724-37. PMID: 15479938.
11. Biertho L, Lebel S, Marceau S, Hould FS, Lescelleur O, Marceau P, et al. Laparoscopic sleeve gastrectomy: with or without duodenal switch? A consecutive series of 800 cases. Digestive surgery. 2014;31(1):48-54. PMID: 24819497.
12. Marceau P, Cabanac M, Frankham PC, Hould FS, Lebel S, Marceau S, et al. Accelerated satiation after duodenal switch. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2005;1(4):408-12. PMID: 16925259.
13. Marceau P, Hould FS, Lebel S, Marceau S, Biron S. Malabsorptive obesity surgery. The Surgical clinics of North America. 2001;81(5):1113-27. PMID: 11589248.
14. Marceau S, Biron S, Lagace M, Hould FS, Potvin M, Bourque RA, et al. Biliopancreatic Diversion, with Distal Gastrectomy, 250 cm and 50 cm Limbs: Long-term Results. Obes Surg. 1995;5(3):302-7. PMID: 10733816.
15. Smith J, Cianflone K, Biron S, Hould FS, Lebel S, Marceau S, et al. Effects of maternal surgical weight loss in mothers on intergenerational transmission of obesity. The Journal of clinical endocrinology and metabolism. 2009;94(11):4275-83. PMID: 19820018.

16. Mathus-Vliegen EM. Obesity and the elderly. Journal of clinical gastroenterology. 2012;46(7):533-44. PMID: 22772735.
17. Lynch J, Belgaumkar A. Bariatric surgery is effective and safe in patients over 55: a systematic review and meta-analysis. Obes Surg. 2012;22(9):1507-16. PMID: 22718467.
18. Han TS, Tajar A, Lean ME. Obesity and weight management in the elderly. British medical bulletin. 2011;97:169-96. PMID: 21325341.
19. Contreras JE, Santander C, Court I, Bravo J. Correlation between age and weight loss after bariatric surgery. Obes Surg. 2013;23(8):1286-9. PMID: 23462862.
20. O'Keefe KL, Kemmeter PR, Kemmeter KD. Bariatric surgery outcomes in patients aged 65 years and older at an American Society for Metabolic and Bariatric Surgery Center of Excellence. Obes Surg. 2010;20(9):1199-205. PMID: 20532834.
21. Scozzari G, Passera R, Benvenga R, Toppino M, Morino M. Age as a long-term prognostic factor in bariatric surgery. Annals of surgery. 2012;256(5):724-8; discussion 8-9. PMID: 23095615.
22. van Rutte PW, Smulders JF, de Zoete JP, Nienhuijs SW. Sleeve gastrectomy in older obese patients. Surgical endoscopy. 2013;27(6):2014-9. PMID: 23344504.
23. Leivonen MK, Juuti A, Jaser N, Mustonen H. Laparoscopic sleeve gastrectomy in patients over 59 years: early recovery and 12-month follow-up. Obes Surg. 2011;21(8):1180-7. PMID: 21625908.
24. Dorman RB, Abraham AA, Al-Refaie WB, Parsons HM, Ikramuddin S, Habermann EB. Bariatric surgery outcomes in the elderly: an ACS NSQIP study. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract. 2012;16(1):35-44; discussion PMID: 22038414.
25. Flum DR, Salem L, Elrod JA, Dellinger EP, Cheadle A, Chan L. Early mortality among Medicare beneficiaries undergoing bariatric surgical procedures. JAMA. 2005;294(15):1903-8. PMID: 16234496.
26. Dunkle-Blatter SE, St Jean MR, Whitehead C, Strodel W, 3rd, Bennotti PN, Still C, et al. Outcomes among elderly bariatric patients at a high-volume center. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2007;3(2):163-9; discussion 9-70. PMID: 17331804.
27. Quebbemann B, Engstrom D, Siegfried T, Garner K, Dallal R. Bariatric surgery in patients older than 65 years is safe and effective. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2005;1(4):389-92; discussion 92-3. PMID: 16925254.
28. Sugerman HJ, DeMaria EJ, Kellum JM, Sugerman EL, Meador JG, Wolfe LG. Effects of bariatric surgery in older patients. Annals of surgery. 2004;240(2):243-7. PMID: 15273547.
29. Wittgrove AC, Martinez T. Laparoscopic gastric bypass in patients 60 years and older: early postoperative morbidity and resolution of comorbidities. Obes Surg. 2009;19(11):1472-6. PMID: 19705206.
30. Hazzan D, Chin EH, Steinhagen E, Kini S, Gagner M, Pomp A, et al. Laparoscopic bariatric surgery can be safe for treatment of morbid obesity in patients older than 60 years. Surgery for obesity and related diseases : official

journal of the American Society for Bariatric Surgery. 2006;2(6):613-6. PMID: 17138231.

31. Nelson LG, Lopez PP, Haines K, Stefan B, Martin T, Gonzalez R, et al. Outcomes of bariatric surgery in patients > or =65 years. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2006;2(3):384-8. PMID: 16925358.
32. Frutos MD, Lujan J, Hernandez Q, Valero G, Parrilla P. Results of laparoscopic gastric bypass in patients > or =55 years old. Obes Surg. 2006;16(4):461-4. PMID: 16608611.
33. Sosa JL, Pombo H, Pallavicini H, Ruiz-Rodriguez M. Laparoscopic gastric bypass beyond age 60. Obes Surg. 2004;14(10):1398-401. PMID: 15603658.
34. Nehoda H, Hourmont K, Sauper T, Mittermair R, Lanthaler M, Aigner F, et al. Laparoscopic gastric banding in older patients. Archives of surgery. 2001;136(10):1171-6. PMID: 11585511.
35. Wool D, Bellatorre N, Wren S, Eisenberg D. Male patients above age 60 have as good outcomes as male patients 50-59 years old at 1-year follow-up after bariatric surgery. Obes Surg. 2009;19(1):18-21. PMID: 18855082.
36. Trieu HT, Gonzalvo JP, Szomstein S, Rosenthal R. Safety and outcomes of laparoscopic gastric bypass surgery in patients 60 years of age and older. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2007;3(3):383-6. PMID: 17400516.
37. Ritz P, Topart P, Benchetrit S, Tuyeras G, Lepage B, Mouiel J, et al. Benefits and risks of bariatric surgery in patients aged more than 60 years. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2014. PMID: 24708912.
38. Gastrointestinal surgery for severe obesity: National Institutes of Health Consensus Development Conference Statement. The American journal of clinical nutrition. 1992;55(2 Suppl):615S-9S. PMID: 1733140.
39. Musella M, Milone M, Maietta P, Bianco P, Coretti G, Pisapia A, et al. Bariatric surgery in elderly patients. A comparison between gastric banding and sleeve gastrectomy with five years of follow up. International journal of surgery. 2014;12 Suppl 2:S69-72. PMID: 25159229.
40. Panunzi S, De Gaetano A, Carnicelli A, Mingrone G. Predictors of Remission of Diabetes Mellitus in Severely Obese Individuals Undergoing Bariatric Surgery: Do BMI or Procedure Choice Matter? A Meta-Analysis. Annals of surgery. 2014. PMID: 25361217.
41. Buchwald H, Estok R, Fahrbach K, Banel D, Sledge I. Trends in mortality in bariatric surgery: a systematic review and meta-analysis. Surgery. 2007;142(4):621-32; discussion 32-5. PMID: 17950357.
42. Kim WW, Gagner M, Kini S, Inabnet WB, Quinn T, Herron D, et al. Laparoscopic vs. open biliopancreatic diversion with duodenal switch: a comparative study. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract. 2003;7(4):552-7. PMID: 12763415.
43. Gebhart A, Young MT, Nguyen NT. Bariatric surgery in the elderly: 2009-2013. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2014. PMID: 25130515.

590 44. Sherman V. Commentary on: Bariatric surgery in the elderly: 2009-2013. Surgery
591 for obesity and related diseases : official journal of the American Society for
592 Bariatric Surgery. 2014. PMID: 25443056.
593 45. Willkomm CM, Fisher TL, Barnes GS, Kennedy CI, Kuhn JA. Surgical weight
594 loss >65 years old: is it worth the risk? Surgery for obesity and related diseases :
595 official journal of the American Society for Bariatric Surgery. 2010;6(5):491-6.
596 PMID: 20870182.
597 46. Mingrone G, Panunzi S, De Gaetano A, Guidone C, Iaconelli A, Leccesi L, et al.
598 Bariatric surgery versus conventional medical therapy for type 2 diabetes. The
599 New England journal of medicine. 2012;366(17):1577-85. PMID: 22449317.

600

FIGURE HEADINGS

Figure 1: (A) Percentage of excess weight loss (%EWL) for the two groups after 6, 12, 24, 36, 48 and 60 months of follow-up; (**B**) %EWL, (**C**) percentage of total body weight loss and (**D**) BMI for the two groups after a mean follow-up of 7.1±4.1 years. Mean ± SEM are shown. * $p \leq 0.05$

Figure 2: Resolution of type 2 diabetes, hypertension and obstructive sleep apnea in each group after a mean follow-up of 7.1±4.1 years. **(A)** Percentage of patients with type 2 diabetes resolved, improved, unchanged or unknown; **(B)** Percentage of patients with hypertension resolved, improved, unchanged or unknown; **(C)** Percentage of patients with obstructive sleep apnea resolved, improved, unchanged or unknown. * Statistically significant difference between younger and elderly patients using chi-square test ($p=0.008$)

Figure 3: Mean levels of **(A)** albumin (g/L) (Elderly patients: n=51; Younger patients: n=46), **(B)** calcium (g/L) (Elderly patients: n=54; Younger patients: n=43), **(C)** hemoglobin (g/L) (Elderly patients: n=63; Younger patients: n=53) and **(D)** iron (mmol/L) (Elderly patients: n=72; Younger patients: n=56) prior to and 5 years after BPD-DS in elderly and younger patients. Mean ± SEM are shown. Repeated-measures analysis of variance was used to examine the effect of group [younger patients (age $\leq$ 55 years) versus elderly patients (age $\geq$ 60 years)], time (pre-BPD-DS and 5 years post-BPD-DS) and time-by-group interaction.

TABLES

Table 1: Preoperative characteristics of the study population

Variables	All	Age ≤ 55 years	Age ≥ 60 years	P value
Patients (n)	210	105	105	-
Gender (M : F)	82 : 128	41 : 64	41 : 64	NS
Age (years)	51.4±12.1	40.4±7.0	62.3±2.0	≤0.0001
BMI (kg/m^2)	50.9±6.8[a]	50.9±6.8	50.9±6.8	NS
Weight (kg)	138±26	142±27	133±24	≤0.05
Preoperative comorbidities				
Diabetes	57% (120)	57% (60)	57% (60)	NS
Cardiovascular disease	20% (42)	8% (8)	32% (34)	≤0.0001
Hypertension	72% (151)	63% (66)	81% (85)	0.004
Dyslipidemia	38% (79)	33% (35)	42% (44)	0.20
Obstructive sleep apnea	64% (134)	56% (59)	71% (75)	0.02
Mean number of comorbidities	4.3±2.0	3.8±1.9	4.7±2.1	0.002

Data are presented as mean ± SD or percentage (n). Wilcoxon test was used for analysis of age, BMI, weight and number of comorbidities; Chi-square test was used for analysis of gender and preoperative comorbidities. The two groups were matched for age, gender, BMI, diabetes and the year of operation. M= male, F= female, BMI= body mass index

[a] range=40.1-75.9kg/m^2

Table 2: Perioperative data

Variables	All	Age ≤ 55 years	Age ≥ 60 years	P value
Operative time (min)	170.5±44.1	162.5±39.9	178.6±46.7	0.01
Blood loss (ml)	542±399	474±241	593±484	0.05
Postoperative hospital stay (d)	8.2±6.1	6.4±2.2	10.2±8.3	0.0001
30-day mortality rate	0.9% (2)	0.9% (1)	0.9% (1)	NS
10-day reoperation rate	4.3% (1)	3.8% (4)	4.8% (5)	NS

Data are presented as mean ± SD or percentage (n). Student's *t* test was used for analysis of operative time, blood loss and postoperative hospital stay; Chi-square test was used for analysis of mortality rate and reoperation rate. d=days

637 **Table 3: Major complications in first 30 postoperative days**

Variables	All (n=210)	Age ≤ 55 years (n=105)	Age ≥ 60 years (n=105)	P value
Major				
Gastric leak	0.9% (2)	0.9% (1) [a]	0.9% (1)	NS
Duodenal leak	2.4% (5)	1.9% (2)	2.9% (3)	NS
Ileoileal anastomosis leak	0.5% (1)	0	0.9% (1)	NS
Intra-abdominal abscess	1.9% (4)	0.9% (1)	2.9% (3)	NS
Pancreatitis	0.9% (2)	0	1.9% (2)	NS
Biliary leak	0.5% (1)	0.9% (1)	0	NS
Pneumonia	0.9% (2)	0.9% (1)	0.9% (1)	NS
Abdominal hemorrhage	0.9% (2)	1.9% (2)	0	0.16
Pulmonary embolism	0.5% (1)	0	0.9% (1)	NS
Small bowel obstruction	1.4% (3)	0.9% (1)	1.9% (2)	NS
Stenosis	0.5% (1)	0	0.9% (1)	NS
Others	0.9% (2)	0	1.9% (2) [a]	0.16
Total	12.4% (26)	8.6% (9)	16.2% (17)	0.09

638 Data are presented as percentage (n). Chi-square test was used for analysis of variables. [a]
639 including one death

640

641 **Table 4: Minor complications in the first 30 postoperative days**

Variables	All (n=210)	Age ≤ 55 years (n=105)	Age ≥ 60 years (n=105)	P value
Minor				
Wound infection	1.9% (4)	0.9% (1)	2.9% (3)	NS
Food intolerance	4.8% (10)	4.8% (5)	4.8% (5)	NS
Urinary complications	0.9% (2)	0	1.9%(2)	NS
Atelectasia	0.9% (2)	0	1.9% (2)	NS
Respiratory insufficiency	0.9% (2)	0	1.9% (2)	NS
Digestive hemorrhage	0.9% (2)	0.9% (2)	0	NS
Renal colic	0.5% (1)	0.9% (1)	0	NS
Dyspepsia	0.5% (1)	0.9% (1)	0	NS
Total	11.4% (24)	9.5% (10)	13.3% (14)	NS

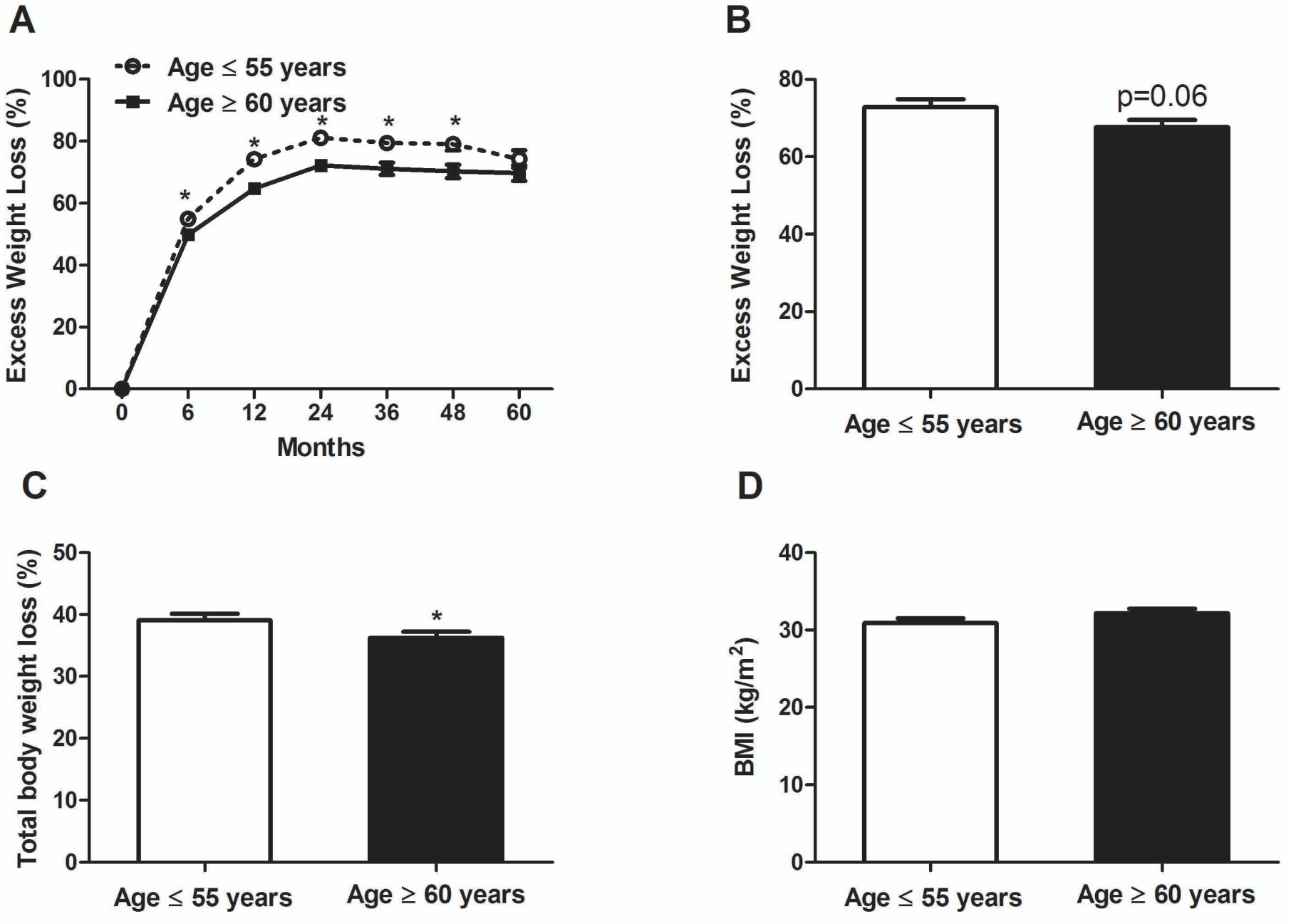
642 Data are presented as percentage (n). Chi-square test was used for analysis of variables.

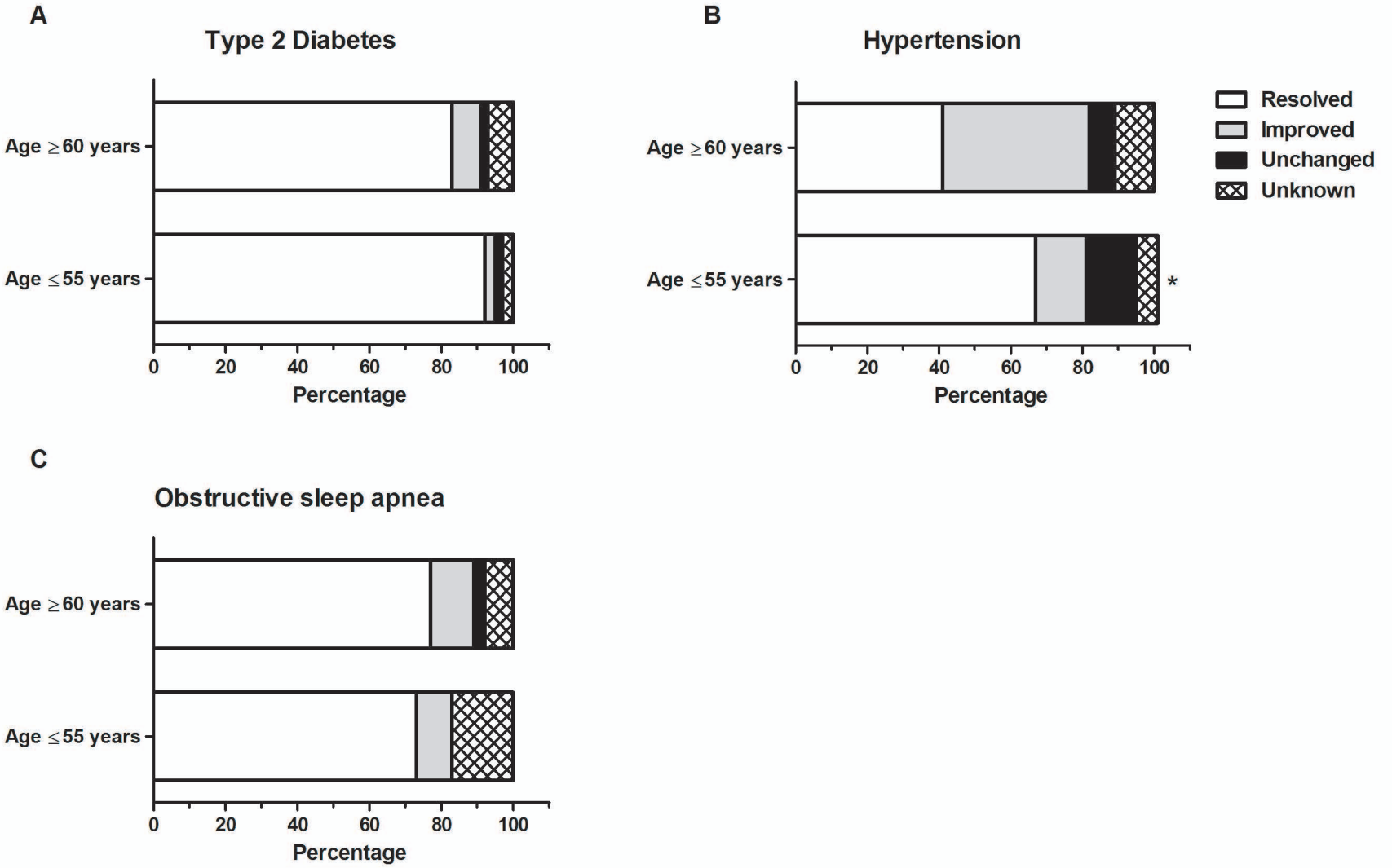
643

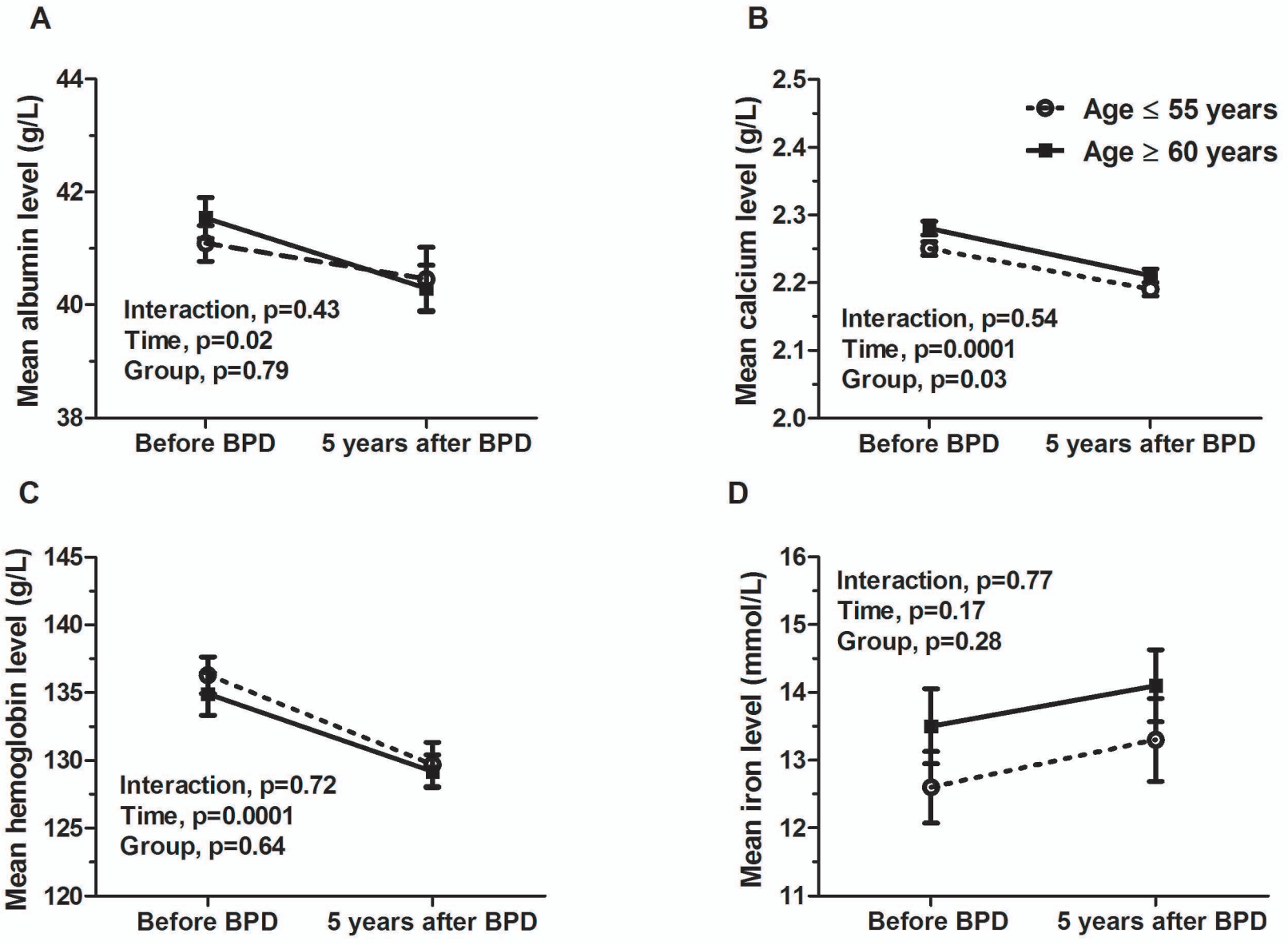
644 **Table 5: Causes of late hospitalization related to bariatric surgery during follow-up**

	All	Age ≤ 55 years		Age ≥ 60 years	
Variables	**% (n)**	**% (n)**	**Required surgery**	**% (n)**	**Required surgery**
Malnutrition	8.1% (17)	4.8% (5)	0.9% (1)	11.4% (12)[a]	1.4% (3)
Food intolerance	1.4% (3)	1.9% (2)	0	0.9% (1)	0.9% (1)
Delayed fistula	2.9% (6)	1.9% (2)	1.9% (2)	3.8% (4)	2.9% (3)
Stenosis	1.4% (3)	1.9% (2)	1.9% (2)	0.9% (1)	0
Incisional hernia	3.8% (8)	4.8% (5)	4.8% (5)	2.9% (3)	2.9% (3)
Gastrointestinal bleeding	0.5% (1)	0	0	0.9% (1)	0
Intestinal obstruction	5.2% (11)	7.6% (8)	7.6% (8)[b]	2.9% (3)	0.9% (1)
Diarrhea	0.9% (2)	1.9% (2)	0	0	0
Abdominal pain	3.3% (7)	3.8% (4)	0	2.9% (3)	0
Pulmonary embolism	0.5% (1)	0	0	0.9% (1)	0
Pancreatitis	0.5% (1)	0.9% (1)	0	0	0
Abscess	2.4% (5)	2.9% (3)	2.9% (3)	1.9 (2)	1.9% (2)

645 Data are presented as percentage (n). Chi-square test was used for analysis of
646 variables. [a]$p \leq 0.10$, comparing percentage of hospitalizations between elderly and younger
647 patients; [b]$p \leq 0.05$, comparing percentage of patients who required surgery between elderly
648 and younger patients.


A
Age ≤ 55 years
Age ≥ 60 years
Excess Weight Loss (%)
100
80
60
40
20
0
0
6
12
24
36
48
60
Months
*
B
Excess Weight Loss (%)
80
60
40
20
0
p=0.06
Age ≤ 55 years
Age ≥ 60 years
C
Total body weight loss (%)
50
40
30
20
10
0
*
Age ≤ 55 years
Age ≥ 60 years
D
BMI (kg/m2)
40
30
20
10
0
Age ≤ 55 years
Age ≥ 60 years


A
Type 2 Diabetes
Age ≥60 years
Age ≤55 years
0
20
40
60
80
100
Percentage
B
Hypertension
Age ≥60 years
Age ≤55 years
*
0
20
40
60
80
100
Percentage
Resolved
Improved
Unchanged
Unknown
C
Obstructive sleep apnea
Age ≥60 years
Age ≤55 years
0
20
40
60
80
100
Percentage


A
Mean albumin level (g/L)
44
42
40
38
Interaction, p=0.43
Time, p=0.02
Group, p=0.79
Before BPD
5 years after BPD
B
Mean calcium level (g/L)
2.5
2.4
2.3
2.2
2.1
2.0
Age ≤ 55 years
Age ≥ 60 years
Interaction, p=0.54
Time, p=0.0001
Group, p=0.03
Before BPD
5 years after BPD
C
Mean hemoglobin level (g/L)
145
140
135
130
125
120
Interaction, p=0.72
Time, p=0.0001
Group, p=0.64
Before BPD
5 years after BPD
D
Mean iron level (mmol/L)
16
15
14
13
12
11
Interaction, p=0.77
Time, p=0.17
Group, p=0.28
Before BPD
5 years after BPD