

Original article

Correlations between intra-abdominal pressure and obesity-related co-morbidities

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Abstract

Background: Obesity is associated with chronic increases in intra-abdominal pressure (IAP). The aim of the present study was to examine the correlation between the IAP and the number of obesity-related co-morbidities.

Methods: A total of 63 morbidly obese patients who were undergoing bariatric surgery had their IAP measured intraoperatively while in a supine position and under general anesthesia. The IAP readings were obtained through an indwelling urinary bladder catheter. The correlation of obesity-related co-morbidities, including systemic hypertension, type 2 diabetes mellitus, gastroesophageal reflux disease, urinary stress incontinence, lower extremity edema, obstructive sleep apnea, and abdominal wall hernia, and the level of IAP were examined using a stepwise regression analysis model.

Results: Of the 62 patients, 57 were women. The mean age was 44 ± 11 years, and the body mass index was 49 ± 10 kg/m². Of the 62 patients, 48 (77%) had an elevated IAP (≥ 9 cm H₂O). A significant and positive correlation was found between the IAP level and the number of obesity-related co-morbidities (Pearson's $r = .8$; $P < .05$). Stepwise logistic regression analysis revealed that systemic hypertension, American Society of Anesthesiologists score, and body mass index were predictors of elevated IAP. A normal IAP appeared to offer a protective effect against systemic hypertension.

Conclusion: In this cohort of mainly obese women, the baseline IAP of morbidly obese patients was abnormally elevated. A greater IAP correlated with the presence of a greater number of obesity-related co-morbid conditions. Systemic hypertension was significantly associated with an elevated IAP. Chronic increases in IAP might, in part, be responsible for the pathogenesis of systemic hypertension in the morbidly obese. (Surg Obes Relat Dis 2009;5:524–528.) © 2009 American Society for Metabolic and Bariatric Surgery. All rights reserved.

Keywords:

Intra-abdominal pressure; Co-morbidities; Morbid obesity; Bariatric surgery

Morbid obesity continues to be a major public health problem in the United States. It is well known that morbid obesity is associated with multiple medical conditions, and most of these conditions improve significantly or resolve after bariatric surgery. One of the proposed mechanisms for

the development of obesity-related co-morbidities is the presence of a chronically increased intra-abdominal pressure (IAP) [1–3]. It has been proposed that a number of the co-morbidities that accompany morbid obesity are related to this pathophysiologic intra-abdominal condition. The decrease in IAP that accompanies significant weight loss might, in part, be responsible for the improvement and resolution of some of these co-morbidities.

In the present study, we measured the intraoperative IAP using an indwelling urinary catheter in morbidly obese patients undergoing bariatric surgery. We examined the correlation between the IAP levels and the presence of

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obesity-related co-morbid conditions and determined the predictors of an elevated IAP in the morbidly obese.

Methods

Morbidly obese patients who underwent laparoscopic gastric bypass or laparoscopic adjustable gastric banding for the treatment of morbid obesity and related co-morbid conditions were enrolled in the present study. Preoperative IAP readings were obtained during surgery, after the induction of general anesthesia and with the patient in the supine position. We recorded the presence of obesity-related co-morbidities that are commonly associated with an increased IAP, including systemic hypertension, type 2 diabetes, gastroesophageal reflux disease, urinary stress incontinence, lower extremity edema, obstructive sleep apnea, and abdominal wall hernia. The demographic and clinical data were also collected. The institutional review board of the University of California, Irvine, Medical Center (Orange, CA) approved the study.

IAP measurement

A 16F indwelling Foley transurethral bladder catheter was inserted after the induction of general anesthesia, with the patient placed in the supine position. Bladder pressure measurement techniques using indwelling transurethral bladder catheters have been previously described and validated [3–5]. The bladder pressures were measured immediately after anesthesia and before standard laparoscopic Roux-en-Y gastric bypass or laparoscopic adjustable gastric banding. With the patient in the supine position, the urinary bladder was partially drained by gravity, with the catheter positioned at the level of the heart. The urinary catheter was then raised above the pubic symphysis. The IAP, measured in centimeters of water, represented the column of urine above the pubic symphysis at the end of expiration.

Statistical analysis

Correlations between the IAP levels and the number of obesity-related conditions were performed using Pearson's correlation. Associations between these variables were tested with chi-square analysis. A linear stepwise logistic regression analysis, with the IAP as the dependent variable, was completed, controlling for the following variables: age, gender, race/ethnicity, body mass index (BMI), American Society of Anesthesiologists (ASA) score, and obesity-related co-morbid conditions (systemic hypertension, type 2 diabetes, gastroesophageal reflux disease, urinary stress incontinence, lower extremity edema, obstructive sleep apnea, and abdominal wall hernia). Statistical analysis was performed using the Statistical Package for Social Sciences statistical software (SPSS, Chicago, IL). $P < .05$ was considered statistically significant.

Results

Demographic data

A total of 62 morbidly obese patients who were undergoing bariatric surgery were included in the present study (Table 1). The demographics of the cohort are listed in Table 1. Of the 62 patients, 77% had an elevated intraoperative IAP >9 cm H₂O. The most common co-morbid condition present was systemic hypertension (53.2%), followed by gastroesophageal reflux disease (51.6%), lower extremity edema (40.3%), obstructive sleep apnea (40.3%), diabetes mellitus (25.8%), stress incontinence (24.2%), and abdominal wall hernia (1.6%).

Correlation between IAP and co-morbidities

The overall mean IAP for the entire cohort was elevated at 11 ± 5 cm H₂O. The mean IAP for the morbidly obese patients without co-morbidities was 10 ± 5 cm H₂O. The mean IAP for those with 1, 2, and ≥ 3 co-morbidities was 9 ± 5 , 12 ± 5 , and 14 ± 5 cm H₂O, respectively ($P < .05$ versus no co-morbidities). Fig. 1 shows the significant and positive correlation between the IAP level and the number of obesity-related co-morbidities ($r = .8$; $P < .05$). A significant correlation between the IAP level and BMI ($r = .5$; $p < .05$) was also noted.

Systemic hypertension was significantly associated with elevated IAP, but the other obesity-related co-morbid conditions were not (Table 2). A normal IAP appeared to offer a protective effect against systemic hypertension. In turn, morbidly obese patients with a normal IAP were 77% less likely to have systemic hypertension (odds ratio .23, 95% confidence interval .06–.81). Establishing IAP as the dependent variable and after controlling for age, gender, race/ethnicity, and all obesity-related co-morbid conditions, step-

Table 1
Patient demographics

Variable	Value
Patients (n)	62
Gender (%)	
Female	86
Male	14
Race/ethnicity (%)	
White	81
Black	14
Hispanic	5
Mean age (yr)	44 ± 11
Mean BMI (kg/m ²)	49 ± 10
Mean ASA score	3 ± 0.2
Bariatric procedure (%)	
LGB	60
LAGB	40

BMI = body mass index; ASA = American Society of Anesthesiologists; LGB = laparoscopic gastric bypass; LAGB = laparoscopic adjustable gastric banding.

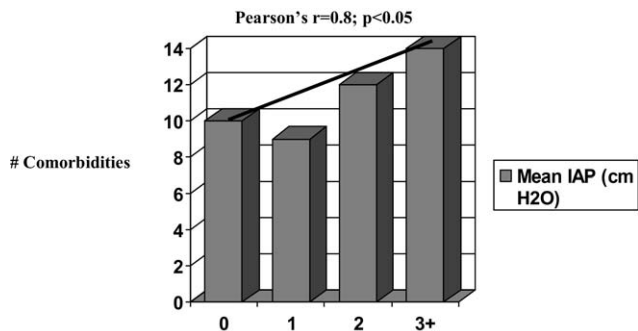


Fig. 1. Correlation between intra-abdominal pressures vs. number of obesity related comorbidities.

wise logistic regression analysis demonstrated that the presence of systemic hypertension, ASA score, and BMI were independent risk factors for an elevated IAP (Table 3).

Discussion

Obesity is associated with multiple obesity-related comorbidities. In the present study, we found that morbidly obese patients undergoing bariatric surgery have an abnormally elevated baseline IAP. We also found that an increasing IAP level correlated with the presence and number of obesity-related co-morbidities. The presence of systemic hypertension, ASA score, and BMI were independent risk factors for an elevated IAP in our morbidly obese patients. Systemic hypertension was the sole obesity-related co-morbidity that was significantly associated with increased IAP, and the other conditions were not. Our results have shown that morbidly obese patients with a normal IAP are less likely to have systemic hypertension.

For the purposes of this investigation, we used a well-established and validated technique with an indwelling transurethral urinary catheter for the intraoperative IAP measurements. Iberti et al. [4,5] previously demonstrated that using a transurethral bladder catheter to monitor the IAP was safe, simple, and highly accurate and correlated

Table 2
Associations between obesity-related co-morbidities and intra-abdominal pressure

Co-morbidity	OR	Chi-square	95% CI
Systemic hypertension	.23	5.61	.06–.81*
Type 2 diabetes mellitus	.36	1.61	.07–1.82
Gastroesophageal reflux disease	1.09	.02	.34–3.50
Urinary stress incontinence	1.85	.90	.51–6.65
Obstructive sleep apnea	.49	1.15	.13–1.80
Lower extremity edema	.65	.40	.17–2.43
Abdominal wall hernia	0	.32	NA

OR = odds ratio; CI = confidence interval; NA = not applicable (unable to calculate).

* P < .05 by chi-square analysis.

Table 3
Stepwise regression analysis model and independent risk factors for elevated intra-abdominal pressure

Variable	Coefficient	SE	T-statistic
Constant	–33.4	8.48	–3.94
ASA score	9.74	2.72	3.59*
BMI	.28	.04	5.89*
Systemic hypertension	2.92	1.00	2.92*

SE = standard error; other abbreviations as in Table 1.

Variables not included in model: age, gender, race/ethnicity, type 2 diabetes mellitus, gastroesophageal reflux disease, lower extremity edema, urinary stress incontinence, obstructive sleep apnea, and abdominal wall hernia.

* P < .05.

significantly with direct intraperitoneal pressure monitoring in various patient positions. The normal mean IAP in hospitalized patients has also been previously established by Sanchez et al. [6] to be ≤9 cm H₂O. They also found a positive correlation between IAP and the BMI.

Increases in IAP can be acute, such as in the case of abdominal compartment syndrome, or chronic, such as during pregnancy or with the development of ascites or morbid obesity. Acute increases of IAP have tremendous deleterious cardiovascular, renal, pulmonary, and splanchnic effects [7–12]. As such, abdominal compartment syndrome requires emergent abdominal decompression. In contrast, the chronic elevation of IAP, such as in the morbidly obese, might be, in part, responsible for development of many comorbid conditions, such as hypertension, type 2 diabetes, gastroesophageal reflux disease, urinary stress incontinence, lower extremity edema, venous stasis, pseudotumor cerebri, obstructive sleep apnea, and abdominal wall hernia [13]. Most of these medical conditions have been shown to improve or resolve after surgically induced weight loss [14,15].

It is possible that the decrease in abdominal and visceral fat that results in the reduction in IAP seen after bariatric surgery is in part responsible for the resolution or improvement of most of the obesity-related conditions. Increased visceral adiposity has also been associated with the development of various metabolic diseases. Sugerman et al. [16] demonstrated that an increased sagittal abdominal diameter and waist circumference were associated with increased urinary bladder pressures in both men and women. Morbidly obese men, who preferentially have a visceral fat distribution, had a greater sagittal abdominal diameter and urinary bladder pressures compared with women. However, in women, no correlation was found between the urinary bladder pressure and waist-to-hip ratio. This phenomenon can be explained by the gender differences in abdominal and visceral fat distributions. Women preferentially have peripheral fat distribution rather than central. Most recently, the Longitudinal Assessment of Bariatric Surgery also demonstrated strong associations between the BMI and co-morbid

conditions in a large population of morbidly obese with a BMI >40 kg/m² who had undergone bariatric surgery [17].

The other co-morbid conditions studied appear to not be related to an increased IAP, such as type 2 diabetes mellitus, which has been historically associated with IAP. Rubino et al. [18] suggested that the immediate improvement in diabetes after bariatric surgery might be related to changes in gastrointestinal incretins after intestinal bypass and duodenal exclusion. However, additional mechanisms might be involved in diabetes resolution, as demonstrated by Dixon et al. [19]. Gastroesophageal reflux, which has also been typically related to a high IAP, was not found to be associated with the IAP in our study. Most patients who undergo antireflux procedures are not morbidly obese. These findings suggest that in addition to an elevated IAP, a defective antireflux mechanism at the gastroesophageal junction must be present. Obstructive sleep apnea, which has mostly been associated with an increased neck circumference, appeared not to be related to an elevated IAP level. Although we did not control for multiparity in the women, IAP was not associated with urinary incontinence symptoms. Also, lower extremity edema, which is mainly caused by decreased venous return and defective lower extremity vein valve mechanisms, was not directly linked to an elevated IAP. The incidence of abdominal wall hernia in this cohort was too low for any definitive statements.

It was not surprising that the ASA score and BMI were independent risk factors for an elevated IAP. The ASA score is an expression of the number of preoperative co-morbid conditions and the BMI is also known to be directly related to the IAP. In contrast, systemic hypertension was unexpectedly found to be a predictor of elevated IAP. Therefore, we hypothesized that these significant associations might indicate a direct cause-and-effect relationship between chronic intra-abdominal hypertension and systemic hypertension in the morbidly obese. Chronic intra-abdominal hypertension, and secondary renal artery and vena cava compression, decreased venous return, renal hypoperfusion, and, ultimately, activation of the rennin-angiotensin-aldosterone cascade, might explain, in part, the pathogenesis of systemic hypertension in the morbidly obese population. Also, the association between IAP and systemic hypertension has been supported by the gradual decrease in IAP and the slow resolution of systemic hypertension after surgically induced weight loss.

In support of our findings, the direct effects of IAP over the renal juxtaglomerular apparatus, with renin and aldosterone release, have been previously demonstrated in animal models by Bloomfield et al. [20]. A chronically increased IAP in canine models was associated with a significant increase in both systolic and diastolic pressure that normalized after a progressive decrease in IAP [21]. Furthermore, chronic increases in IAP have also been shown to be transduced into other body cavities, such as the intrathoracically and intracranially, such as in the case of pseudotumor cere-

bri [22]. Efforts to decrease the IAP have resulted in diminished intracranial pressures [23].

Our study had a few limitations. We analyzed a small group of morbidly obese patients, mostly women. The small proportion of men did not allow us to make definitive conclusions regarding this subgroup. The co-morbidities analyzed were not classified by severity. We had no long-term follow-up to correlate co-morbidity resolution with any changes in the IAP. The number of patients with ≥ 4 co-morbidities was too low to allow an independent analysis. Finally, it is plausible that the lack of correlation between IAP and co-morbidities other than hypertension might have resulted from the small sample size and a type 2 statistical error.

Conclusion

In the present study, predominantly of obese women, the baseline IAP in the morbidly obese patients was abnormally elevated. The IAP correlated significantly with the number of obesity-related co-morbid conditions. Systemic hypertension was significantly associated with an elevated IAP, and a normal IAP appeared to provide a protective effect against systemic hypertension. Therefore, chronic elevations in IAP might be, in part, responsible for the pathogenesis of systemic hypertension in the morbidly obese. Morbidly obese patients with systemic hypertension should be offered a weight loss and IAP reducing procedure.

Disclosures

Dr. Hinojosa, nothing to disclose; Dr. Nguyen is a consultant for Covidien and Ethicon Endo-Surgery; J. Esteban Varela is a consultant for Ethicon Endo-Surgery.

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Editorial comment

Comment on: Correlations between intra-abdominal pressure and obesity-related co-morbidities

It is always nice to see confirmatory data regarding previous research work. The report by Varela et al. [1] supports our findings regarding the importance of an increase in intra-abdominal pressure (IAP) in obesity co-morbidity [2] (published in the “*Journal of Internal Medicine*” in 1997—after it was rejected by the “*New England Journal of Medicine*,” “*American Journal of Medicine*,” and “*Annals of Internal Medicine*”). This study found direct correlations between the urinary bladder pressure and the body mass index, sagittal abdominal diameter, and waist circumference. However, no correlation was found between the urinary bladder pressure and the waist-to-hip ratio in women—probably because of the much greater amount of peripheral, compared to central, obesity in women than in men. This, as well as the findings from other studies, has disparaged the use of the waist-to-hip ratio when evaluating patients for the metabolic syndrome.

The report by Sugerman and colleagues [2] strongly supports the hypothesis that an increased IAP is at least partially, if not greatly, responsible for systemic hypertension in patients with central obesity, secondary to activation of the juxtaglomerular apparatus, with release of renin and aldosterone and conversion of angiotensinogen to angiotensin I. We performed a number of studies in the laboratory that support this concept. First, increasing IAP in a porcine model was associated with an increase in aldosterone and renin, which decreased after reducing the IAP [3]. Second,

directly increasing the renal venous pressure in a porcine model was also associated with an increase in aldosterone and renin, which decreased after reducing the constriction. This was also associated with proteinuria, which is frequently seen in severely obese patients [4]. Finally, a chronically increased IAP in a canine model was associated with a significant increase in both systolic and diastolic pressures, which decreased with a progressive decrease in the IAP [5].

We have also shown that chronic headache in severely obese patients, termed “pseudotumor cerebri,” is probably secondary to an increased IAP as a result of the increased intrapleural pressure and decreased venous return from the brain [6]. This increase can be obviated in a porcine model with a median sternotomy or in patients with an externally applied negative abdominal pressure device or after surgically induced weight loss in the severely obese [6–9].

A number of other co-morbidities not reach statistical significance in the study by Varela et al. [1], probably because of the inadequate numbers of patients with each co-morbidity, representing a type 2 statistical error the authors acknowledged. In another study, we documented that after surgically induced weight loss, a significant decrease occurs in the IAP that is associated with significant improvement in obesity-related co-morbidities [10].

These data support the hypothesis that pre-eclampsia in pregnancy might be secondary to an increased IAP. In contrast