ORIGINAL ARTICLE

Long-term Changes in Blood Pressure in Extremely Obese Patients Who Have Undergone Bariatric Surgery

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Hypothesis: Systolic and diastolic pressure and the incidence of hypertension in very obese patients decline after bariatric surgery and do not rebound.

Design: Chart review.

Setting: Surgical practice in a university medical center.

Patients: Women and men, 18 years or older, with a body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) of 40 or greater, having no previous surgical intervention for extreme obesity.

Intervention: Vertical-banded gastroplasty or Roux-en-Y gastric bypass.

Main Outcome Measures: Systolic and diastolic blood pressure, BMI, and antihypertensive medications.

Results: Patients underwent Roux-en-Y gastric bypass (n = 285; mean initial BMI, 55.7) or vertical banded gastroplasty (n = 62; mean initial BMI, 48.5); half of each group was hypertensive at evaluation. The BMI dropped in both groups after surgery and stabilized at about 35 within 18 months. Systolic pressure changes were generally modest, although diastolic pressure declined significantly after surgery. In patients with untreated stage 1 hypertension, marked reductions in systolic and diastolic pressures occurred after surgery. Many patients taking antihypertensive medications before surgery discontinued them after surgery and remained normotensive.

Conclusions: Blood pressure reductions that occur after bariatric surgery and substantial weight loss depend on the blood pressure status of patients before surgery: normotensive patients and hypertensive patients taking antihypertensive medications show small postsurgical pressure reductions, while patients with elevated blood pressure before surgery show notable postsurgical pressure drops. The overall incidence of hypertension after bariatric surgery declines substantially and remains low.

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EXCESS BODY WEIGHT LEADS TO high blood pressure[1-5] and, over time, to the development of cardiovascular disease.[6,7] The importance of this link is suggested by the observation that reducing body weight lowers blood pressure and the risk of cardiovascular disease.[8] However, the relationship of body weight (or body mass index [BMI], calculated as weight in kilograms divided by the square of height in meters) to blood pressure has focused primarily on individuals around the population mean[2,9,10] and has not been carefully evaluated at the upper extreme of body weight (or BMI). From published data, the incidence of hypertension in very obese individuals is high (as much as 65%),[1] although few blood pressure data have been reported. Because such individuals have difficulty in reducing body weight (to reduce morbidity) through lifestyle changes or pharmacotherapy, surgical procedures (bariatric surgery) have been developed that reduce the capacity of the stomach to hold food, restrict the flow of food into the small intestine, and, in some procedures, diminish the absorptive capacity of the small intestine.[11] These procedures produce marked, sustained weight loss. However, of the few studies available that measured blood pressure after surgery, the decline in blood pressure was modest in relation to marked reductions in BMI. Moreover, in one study, the effect was transient despite large, sustained reductions in BMI.[12] These findings are surprising in groups undergoing considerable weight reduction, given the significance attached to

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excess body weight for its actions on blood pressure.[4] Because the bariatric surgical patient presents an opportunity to examine the relationship between BMI and blood pressure over a range of body weights not typically studied, and because the blood pressure database in such individuals is small, we examined this relationship further via a chart review of a large number (n=347) of bariatric surgical patients. Most of these patients had submitted to a type of bariatric surgery that produces very large, sustained losses in weight (Roux-en-Y gastric bypass [RGB]).

METHODS

A chart review was conducted of all bariatric surgical patients treated by one of us (A.P.C.) who received an initial surgical evaluation between January 14, 1992, and November 20, 2001. The only inclusion criterion was that the patient had undergone a bariatric surgical procedure; the only exclusion criterion was the occurrence of more than one bariatric procedure (ie, a vertical banded gastroplasty [VBG] later converted to an RGB). The charts were kept by the surgeon and contained records pertaining to preoperative evaluations, surgical procedure and hospital care, and follow-up monitoring at the surgeon's office. The data collected were weight, height, sex, age, systolic blood pressure, diastolic blood pressure, hypertension medications, and the dates of initial evaluation, surgery, and follow-up visits. Weight and height data were used to calculate the BMI, which was used as the measure of body mass because it is most closely associated with body fat content and the development of comorbid conditions (eg, hypertension and diabetes).[13] For reference, degree of obesity was categorized by BMI as follows: normal (healthy) weight, 18.5 to 24.9; overweight, 25.0 to 29.9; obesity (stage 1), 30.0 to 34.9; obesity (stage 2), 35.0 to 39.9; and extreme obesity, 40.0 or greater.[13] All body weight measurements were made in the surgeon's office by a nurse, using a 450-kg-capacity scale (DIGI, Rice Lake, Wis, or Mettler Toledo, Columbus, Ohio); blood pressure measurements were made a single time at each visit, in the sitting position, using the left arm and a sphygmomanometer and cuff appropriate for the arm circumference. Phase I and phase V Korotkoff sounds were used to determine systolic and diastolic blood pressures. Patients sat quietly in the waiting room for 15 to 20 minutes and then in a treatment room for 5 to 10 minutes before blood pressure was measured. At each visit, patients were asked by a nurse to report all medications currently in use; this information was recorded in the medical chart and was used to assess antihypertensive medication history. All data were collected on data sheets that were identified by number only (assigned by an honest broker). The study was approved by the institutional review board of the University of Pittsburgh, Pittsburgh, Pa, as exempt from informed consent.

SURGICAL PROCEDURES

Patients underwent either a VBG or an RGB.[11] The VBG procedures were all performed by the open midline incision technique. A 36F bougie was used to calibrate pouch size, and the gastric outlet was reinforced with a polypropylene cuff (5-cm circumference). The RGB was performed either open or laparoscopically, using a standard Greenville gastric bypass technique.[14] The gastric pouch was measured at its oblique length to 5 cm and either partitioned or divided with staplers. The biliary limb was 50 cm in length, and the Roux limb varied from 150 to 250 cm, based on presurgical BMI: BMI less than 50, 150 cm; BMI of 50 to less than 60, 180 cm; BMI of 60 to less than 70, 220 cm; and BMI of 70 or more, 250 cm.

STATISTICS

Baseline demographic characteristics and clinical measures were compared between the surgery types with χ^2 for contingency tables on categorical variables and group t tests on continuous measures. Statistical significance was defined to be $P<.05$. Longitudinal (time) analyses were conducted by means of a mixed-effect, random coefficient model, which included a random intercept and slope for each subject.[15,16] A quadratic term of week was added to fit the curvature of the data better. The outcome variables were BMI and systolic and diastolic blood pressure over 90 weeks (or 18 months) after surgery. A separate model was run for each grouping variable examined: surgery type (bypass, gastroplasty), blood pressure medication (using, not using), hypertension in patients *not* receiving blood pressure medications (hypertensive, normotensive), antihypertensive "type" (see next paragraph), and age in women (≥50 years, <50 years). Fixed effects of group, time in months after surgery, and group × time interaction are reported. The random coefficient analysis was limited to 90 weeks because after that time, more than 50% of the patients were lost to follow-up.

Hypertension was defined as having a systolic blood pressure of 140 mm Hg or higher, a diastolic blood pressure of 90 mm Hg or higher, or both (stage 1 classification).[17] Because a variety of antihypertensive medications was used by patients being treated for hypertension, and group size for individual drugs was not large enough to analyze each separately, we formed 2 broad groups for statistical analysis, representing (1) medications that influenced renal solutes–water handling (diuretics) and (2) medications that primarily affected total peripheral resistance (adrenergic blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, and angiotensin II receptor antagonists).

For graphical presentation, because the timing of presurgical and postsurgical clinic visits varied in relation to the date of surgery, data were organized into the following time bins: month 0, initial screening visit for surgery; month 3, clinic visit beginning week 6 through week 19 after surgery; month 6, clinic visit beginning week 20 through week 32 after surgery; month 9, clinic visit beginning week 33 through week 45 after surgery; month 12, clinic visit beginning week 46 through week 64 after surgery; and month 18, clinic visit beginning week 65 through week 90 after surgery.

RESULTS

SAMPLE

Three hundred forty-seven patients were included in the study. Eighty-two percent of the patients underwent RGB and 18%, VBG (**Table 1**). The surgical groups did not differ significantly in age, systolic or diastolic blood pressure, the proportion of women, or the proportion of patients with hypertension (Table 1). There were significant differences in body weight and BMI at initial visit, reflecting the surgeon's algorithm at the time to offer VBG to nondiabetic patients with a BMI less than 50.

EFFECT OF SURGERY TYPE

A significant main effect of sex was not present on systolic or diastolic blood pressure (**Table 2**); men and

Table 1. Characteristics of Study Subjects*

Variable	RGB Group (n = 285)	VBG Group (n = 62)	χ^2 or *t* Value	*df*	*P* Value
Age, y	40.6 ± 9.4	39.2 ± 10.9	1.04	341	.30
Sex, % F	77.5	77.4	0.01	1	.98
Weight, kg	157.3 ± 37.2	138.2 ± 36.0	3.67	344	<.001
BMI	55.7 ± 11.3	48.5 ± 9.3	4.67	344	<.001
Systolic BP, mm Hg	135.5 ± 15.3	131.8 ± 15.4	1.67	329	.10
Diastolic BP, mm Hg	82.5 ± 7.2	81.9 ± 8.2	0.63	329	.53
Hypertensive group,† No. (%)					
Hypertensive	74 (26)	15 (24)	0.08	1	.77
Antihypertensive medication user	89 (31)	14 (23)	2.11	1	.15
Total	**163** (57)	**29** (47)	2.24	1	.14

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); BP, blood pressure; RGB, Roux-en-Y gastric bypass; VBG, vertical-banded gastroplasty.

*Data are given as mean ± SD unless otherwise specified.

†A patient was considered "hypertensive" if he or she was not taking antihypertensive medications and had a systolic BP of 140 mm Hg or more, or a diastolic BP of 90 mm Hg or more. An "antihypertensive medication user" was any patient actively taking 1 or more antihypertensive medications at initial evaluation.

Table 2. Statistical Analyses (First 90 Weeks of Data)

	Systolic BP			Diastolic BP		
Variable	F	*df*	*P* Value	F	*df*	*P* Value
Surgery, gastric bypass vs gastroplasty						
Group	0.28	1,2602	.60	1.04	1,2598	.31
Time	7.84	1,343	.005	24.36	1,343	.001
Group × time	3.74	1,2602	.05	1.02	1,2298	.31
Sex, M vs F						
Group	0.87	1,2602	.35	0.38	1,2598	.54
Time	5.32	1,343	.02	20.62	1,343	.001
Group × time	0.00	1,2602	.96	0.64	1,2598	.42
BP medications, yes vs no						
Group	35.76	1,2602	.001	9.58	1,2598	.002
Time	4.44	1,343	.04	21.25	1,343	.001
Group × time	3.13	1,2602	.08	4.23	1,2598	.04
Patients taking BP medications, type of medication*						
Group	7.02	1,574	.008	4.43	1,572	.04
Time	2.18	1,75	.14	6.62	1,75	.01
Group × time	0.48	1,574	.49	0.02	1,572	.89
Patients not taking BP medications, normotensive vs hypertensive						
Group	78.46	1,1773	.001	49.56	1,1771	.001
Time	6.05	1,230	.02	21.41	1,230	.001
Group × time	4.15	1,1773	.04	3.73	1,1771	.05
Women, age <50 y vs ≥50 y†						
Group	6.55	1,1532	.01	0.51	1,1530	.48
Time	6.68	1,257	.01	20.96	1,257	.001
Group × time	4.35	1,1532	.04	0.69	1,1530	.41

Abbreviation: BP, blood pressure.

*Patients taking BP medications were analyzed according to their classification in 1 of 2 broad drug classes: (1) drugs that modify heart function or peripheral resistance (catecholamine agonists and antagonists, calcium channel blockers, angiotensin-converting enzyme inhibitors, and angiotensin-II receptor antagonists) and (2) drugs that modify renal handling of water and electrolytes (diuretics).

†Divided by age to evaluate the effect of menopause.

women were thus analyzed together. Significant effects of surgical procedure and time were noted on BMI, and a significant interaction term was present (**Figure 1**A). The average BMI in patients who underwent RGB decreased from 55.7 to a low of 35.5 at 18 months after surgery, a reduction of about 36%. In patients who underwent VBG, the BMI declined from 48.5 to a low of 34.3 at 12 months after surgery, a drop of about 29%. Systolic blood pressure declined modestly in both groups (5 to 6–mm Hg mean change to nadir value). There was no significant group (surgical procedure) effect, but the time effect was significant; the interaction term almost reached statistical significance ($P = .053$; Table 2). Diastolic blood pressure declined by 4 to 5 mm Hg (mean change to nadir value). The time effect was significant, but the group effect was not; the interaction term was not significant (Figure 1; Table 2).

EFFECT OF BLOOD PRESSURE MEDICATIONS

Data were evaluated according to whether patients were taking antihypertensive medications at the time of initial visit. Of 347 patients, 103 (30%) took blood pressure medications. With this grouping, BMI showed no group (medication vs no medication) effect, but a significant time effect was present (**Figure 2**A); the interaction term was not significant. For systolic blood pressure, significant group and time effects were present (Figure 2B), but the interaction term did not reach statistical significance (Table 2). The initial mean systolic blood pressure in the medicated group was about 140 mm Hg, higher than the value of 133 mm Hg in the unmedicated group (Figure 2B). Significant group and time effects were also present for diastolic blood pressure; the interaction term was also significant (Figure 2C). The initial mean diastolic pressure in the medicated group was about 84 mm Hg, modestly higher than the value in the unmedicated group (81.7 mm Hg; Figure 2C). In general, it appears that systolic and diastolic blood pressures were higher before and after surgery in patients taking antihypertensive medications than in patients who were not. An assessment was also made of the number of patients who discontinued the use of antihypertensive medications during the follow-up period. A patient was considered to have discontinued drug use if he or she stopped taking the medication at any point after surgery and did not resume by the last follow-up visit. By these criteria, of 103 patients initially taking antihypertensive agents, 35 discontinued drug use during follow-up (34%); the blood pressure of this latter group at their final visit was 137±15 mm Hg systolic and 80±1 mm Hg diastolic.

An analysis was then conducted of patients taking antihypertensive drugs to assess whether broad antihypertensive class influenced postsurgical changes in blood pressure. Two medication classes were constructed: diuretics (n=24) and drugs that reduce total peripheral resistance (n=54; see the "Methods" section). (Of 103 patients taking antihypertensive medications, 25 were excluded from this analysis because they reported using both drug classes together.) As indicated in Table 2, the group effect was statistically significant for both systolic and diastolic blood pressure (pressures were a few millimeters of mercury lower in the diuretic group at almost all time points; data not shown); no time effect was present for systolic blood pressure, but a significant time effect on diastolic pressure occurred (diastolic pressure declined over time). The interaction terms were not significant.

EFFECT OF BLOOD PRESSURE AT INITIAL VISIT IN PATIENTS NOT TAKING ANTIHYPERTENSIVE MEDICATIONS

More than two thirds of the patients (n=244) reported taking no antihypertensive medications at initial visit (or

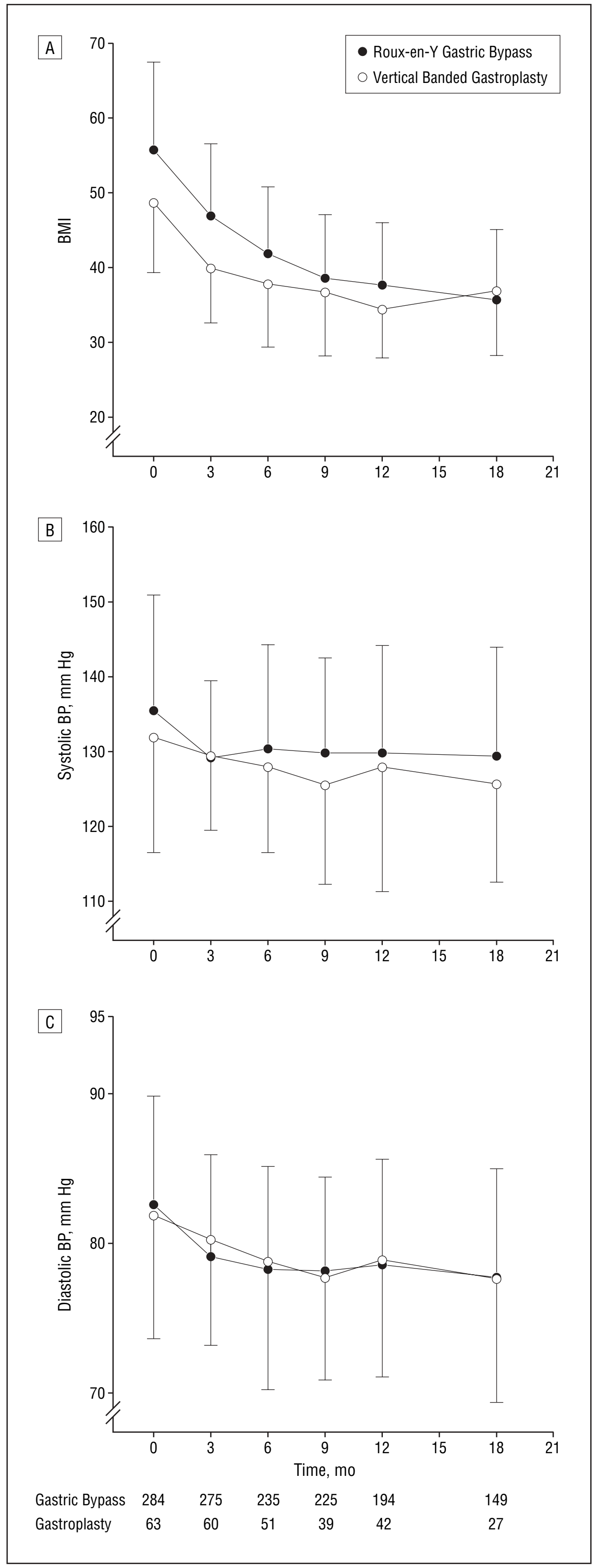

Figure 1. Changes in body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) and systolic and diastolic blood pressure (BP) after bariatric surgery in obese subjects by surgery type. Data are presented as mean±SD. Numbers of patients at each time point for each type of surgery are given at the bottom of the figure. For BMI, main effects of surgical group ($F_{1,2660}$=30.08, $P<.001$) and time ($F_{1,343}$=1840.15, $P<.001$) were noted; the interaction term was also significant ($F_{1,2660}$=29.84, $P<.001$).

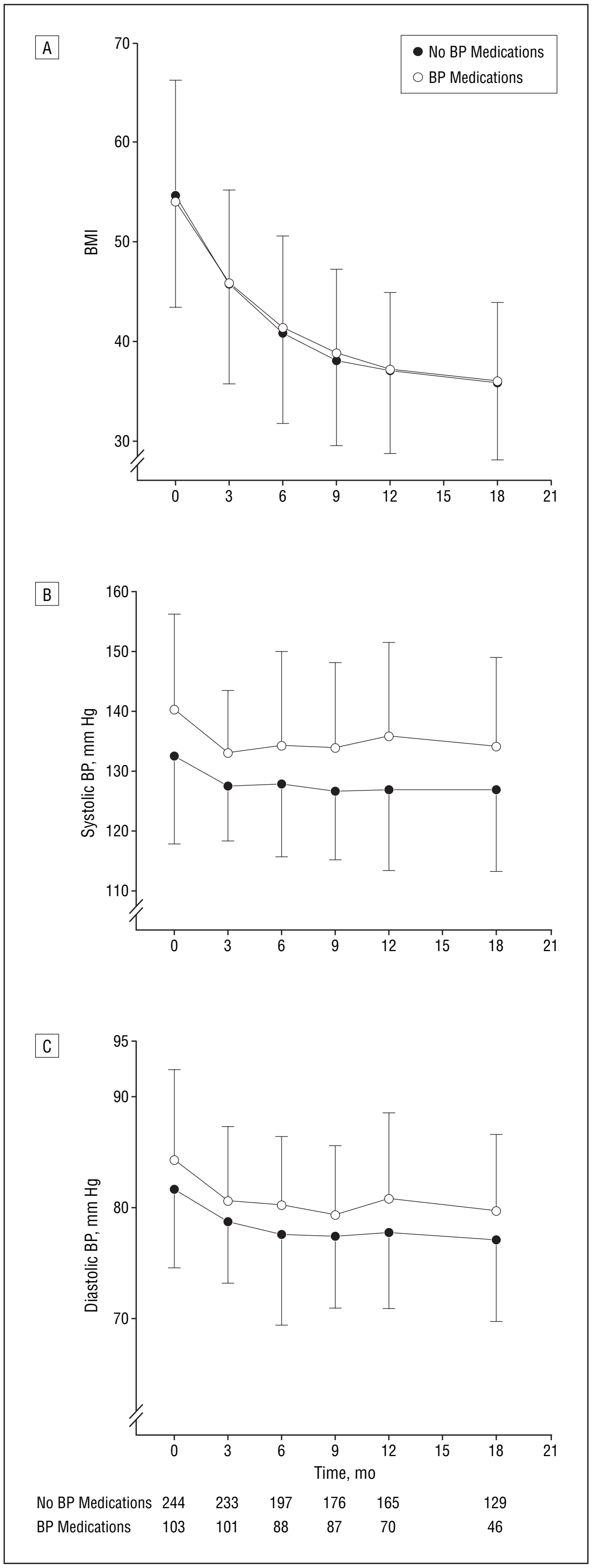

Figure 2. Changes in body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) and systolic and diastolic blood pressure (BP) after bariatric surgery in obese subjects, comparing patients taking medications to control BP vs subjects taking no BP medications. Data are presented as mean ± SD. Numbers of patients at each time point for each medication group are given at the bottom of the figure. For BMI, a main effect of time ($F_{1,343}$=4425.60, $P<.001$) but not medication group ($F_{1,2652}$=0.10, $P=.75$) was noted; the interaction term was not significant ($F_{1,2652}$=2.45, $P=.12$).

throughout the follow-up period). Of this group, roughly one third (89/244) at initial evaluation had systolic and/or diastolic blood pressure readings that placed them in the stage 1 hypertensive category (systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg). When these normotensive and unmedicated hypertensive groups were compared, significant group and time effects were present for BMI; the interaction term was not significant (**Figure 3**A). In general, normotensive patients had a higher BMI than hypertensive patients. The initial mean systolic blood pressure in the hypertensive group was about 145 mm Hg, well above the value in the normotensive group (125 mm Hg) (Figure 3B); a significant group effect was present (Table 2). A statistically significant time effect was also present; the interaction term was also significant (Table 2). In the hypertensive group, mean systolic blood pressure declined about 16 mm Hg in the first 6 to 9 months after surgery; no change was evident in the normotensive group. The initial mean diastolic blood pressure in the hypertensive group was about 87 mm Hg compared with about 79 mm Hg in the normotensive group (Figure 3C). Significant group and time effects were present (Table 2); the interaction term almost reached statistical significance ($P=.054$). Mean diastolic pressure in the hypertensive group declined about 9 mm Hg in the first 6 to 9 months after surgery, but only about 2 mm Hg in the normotensive group.

For patients who were hypertensive at evaluation but not taking antihypertensive medications, an assessment was also made of the number whose blood pressure decreased into the normal range during postsurgical follow-up. A patient's blood pressure was considered to have decreased into the normal range if, on 2 of the last 3 clinic visits, systolic blood pressure was less than 140 mm *and* diastolic pressure was less than 90 mm Hg. By this definition, the blood pressures of 65 (73%) of the 89 unmedicated hypertensive patients had decreased into the normal range by the end of the follow-up period.

EFFECT OF AGE IN WOMEN

Women were divided into 2 age groups, 50 years or older (18% of women) and younger than 50 years (82% of women), to assess whether menopause influenced blood pressure changes after surgery. The average age at menopause in the United States is estimated to be around 50 years.[18] For BMI, a significant time effect was present ($F_{1,258}$=2771, $P<.001$), but the group effect and interaction term were not significant. For systolic blood pressure, significant group (mean systolic blood pressure of women ≥50 years old was consistently 3-5 mm Hg greater than that of women <50 years old) and time (initial 3– to 5–mm Hg drop in pressure, which after 6 months was sustained by women <50 years old but not those ≥50 years old) effects were present, and the interaction term was significant (Table 2). For diastolic blood pressure, a significant time effect was present, but the group effect and interaction term were not significant (diastolic pressure dropped about 4 mm Hg and showed no rebound) (Table 2). When the analysis was restricted to women who were *not* taking antihypertensive medications (188 women, of whom 168 were <50 years old), a similar outcome was obtained: a significant time effect was present for BMI ($F_{1,184}=1422$, $P<.001$), but the group effect and interaction term were not significant. For systolic blood pressure, significant group ($F_{1,1116}=5.31$, $P=.02$) and time ($F_{1,183}=4.48$, $P=.04$) effects were present, while the interaction term was not significant ($F_{1,1116}=1.78$, $P=.18$); for diastolic blood pressure, a significant time effect was present ($F_{1,183}=12.40$, $P<.001$), but the group effect ($F_{1,1115}=2.35$, $P=.13$) and interaction term ($F_{1,1115}=0.0$, $P>.99$) were not significant.

COMMENT

These results confirm that BMI declines notably after either bariatric surgical procedure, reaching a plateau 12 to 18 months after surgery (Figure 1). Associated with this change in BMI were small reductions in systolic and diastolic blood pressure (Figure 1). These blood pressure effects became more interesting when particular patient subgroups were examined. First, patients who were normotensive and taking no blood pressure medications before surgery showed no reduction in systolic blood pressure after surgery and only a small, gradual decline in diastolic blood pressure (black circles in Figure 3). Second, patients under active treatment for hypertension showed very modest reductions in systolic and diastolic blood pressure after surgery (white circles in Figure 2). Third, patients with stage 1 hypertension before surgery who were not receiving active treatment for hypertension showed notable drops in both systolic and diastolic blood pressure after surgery (white circles in Figure 3). The reduction in blood pressure after surgery was therefore most clearly seen in that patient subgroup in which it might most have been expected. In addition, the overall impact of bariatric surgery on hypertension was also evident by the number of hypertensive subjects who were no longer hypertensive after surgery: 192 of 347 subjects had been hypertensive before surgery (103 taking antihypertensive medication and 89 taking no medication but meeting the criteria for stage 1 hypertension), while only 92 subjects remained hypertensive after surgery (68 patients taking antihypertensive medications and 24 taking no medications but having stage 1 hypertension).

Our results are generally consistent with those published previously. The incidence of hypertension in our patient group was around 50%, about half diagnosed and under treatment ("antihypertensive users" in Table 1) and half meeting the definition of stage 1 hypertension at initial evaluation[17] but untreated ("hypertensive" in Table 1). This proportion is similar to that reported in most studies.[12,19-21] Our patients who underwent RGB and VBG had initial BMIs in the 50 to 55 range (group mean values), which is considered to be very obese.[13] During a period of 12 to 18 months after surgery, their BMIs decreased to around 35, a marked decline, although not into the nonobese range.[13] Such reductions appear typical.[12,19,21] We observed that, of patients identified as hypertensive before surgery (ie, they used antihypertensive medications or met the criteria for stage 1 hypertension), about

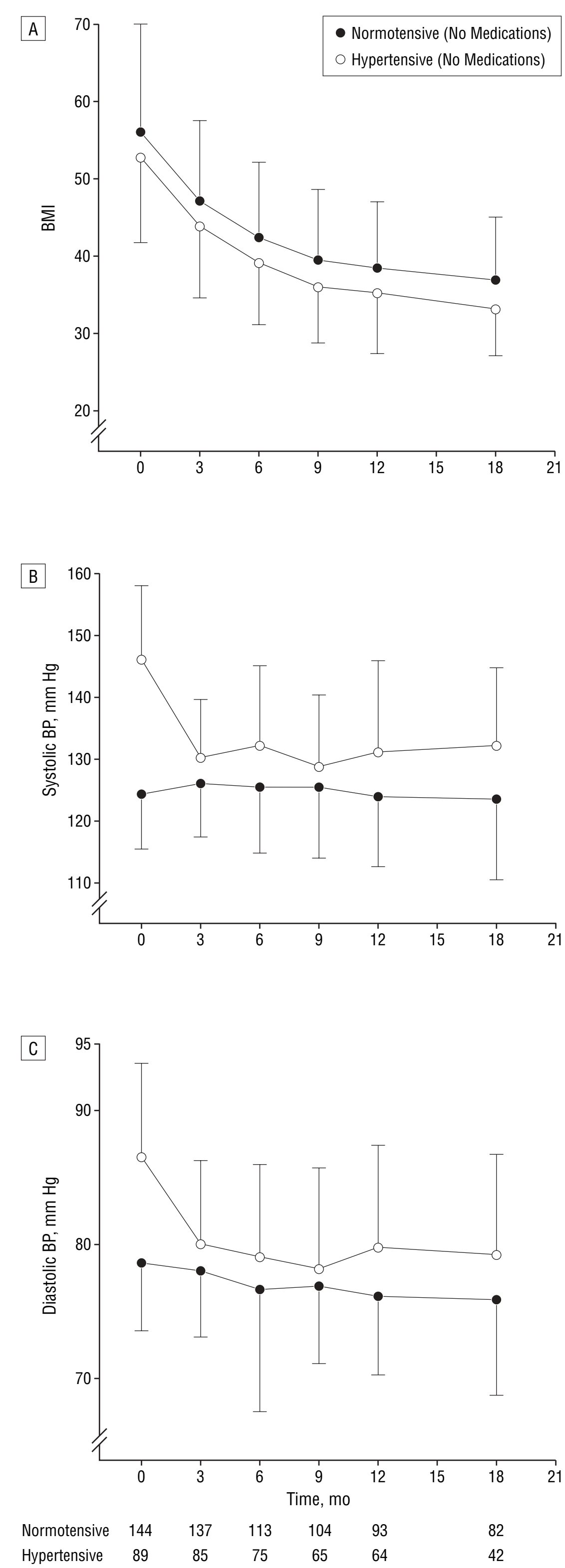

Figure 3. Changes in body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) and systolic and diastolic blood pressure (BP) after bariatric surgery in obese subjects, comparing presence or absence of hypertension in patients taking no BP medications. Data are presented as mean±SD. Numbers of patients at each time point for the normotensive and hypertensive groups are given at the bottom of the figure. For BMI, main effects of group ($F_{1,1807}=4.61$, $P=.03$) and time ($F_{1,230}=2247.49$, $P<.001$) were noted; the interaction term was not significant ($F_{1,1807}=0.96$, $P=.32$).

half were no longer hypertensive (or using drugs) after surgery, a response rate similar to that reported previously.[19-21] However, only a few published studies exist with which to compare the blood pressure changes we observed. Carson et al[21] reported in their normotensive subjects (systolic blood pressure values were not reported for hypertensive subjects) that systolic blood pressure decreased about 10 mm Hg and diastolic pressure about 9 mm Hg 1 year after surgery (BMI decreased from 48.3 to 31.9). Our normotensive patients experienced a similar reduction in BMI but no decline in systolic blood pressure (Figure 3B, black circles). A small decline in diastolic blood pressure was noticeable (Figure 3C, black circles: baseline, 79 mm Hg; 12 months, 77 mm Hg), although the change may not be significant (since the interaction term was significant [$P=.04$] and the reduction was marked in the hypertensive group). This difference may be due to the fact that Carson et al[21] required only that diastolic blood pressure exceed 90 mm Hg for a definition of hypertension. The current definition of stage 1 hypertension is a systolic blood pressure of 140 mm Hg or greater *or* a diastolic blood pressure of 90 mm Hg or higher,[17] and this definition was used in the present study to identify hypertensive subjects. Had we used the definition of Carson et al, most of our unmedicated, stage 1 hypertensive patients would have been included in the "normotensive" group. In this case, the reductions in systolic and diastolic blood pressures would no doubt have been greater in our normotensive group, but we would have missed the sizable blood pressure effects seen with weight loss in stage 1 hypertensive patients. Sjöström et al[12] reported that systolic blood pressure decreased about 11 mm Hg and diastolic pressure about 7 mm Hg 6 months after surgery. However, in their study, systolic and diastolic blood pressure values were noted to be adjusted for the use of antihypertensive medications, but the adjustment procedure was not specified. Systolic and diastolic blood pressure values were not reported separately for subjects who were or were not being treated for hypertension, or for subjects who were normotensive vs hypertensive (untreated). A meaningful comparison is therefore not possible.

One motivation for undertaking this study was the report by Sjöström et al[12] that the decline in blood pressure that follows bariatric surgery is transient and begins to reverse by 1 year after surgery, despite the fact that BMI remained reduced. We saw no evidence that either systolic or diastolic blood pressure began to rise once nadir values had been reached after surgery (within 3-6 months of surgery; Figures 1, 2, and 3). This was particularly evident in the unmedicated hypertensive group, which showed the largest reductions in blood pressure (Figure 3B and C, open circles): after the initial reductions in systolic and diastolic blood pressure, no increases emerged out to the end of the measurement period. Of course, our patient analysis was limited to 90 weeks (about 22 months) after surgery, and it is possible that increases may have occurred after this time. Indeed, the most notable increases reported by Sjöström et al occurred between the second and third years after surgery.[12] We did look at individual systolic and diastolic blood pressure curves for all of our subjects for whom we had data beyond 90 weeks after surgery (data out to 3 years were available for 59 subjects; not shown), and we saw no increases in blood pressure. However, such information is only suggestive and indicates a need for additional, prospective studies with high follow-up rates out to at least 5 years after surgery.

Although the present set of data and previous work suggest that systolic and/or diastolic blood pressure may decline as obese patients lose weight after bariatric surgery, the changes in blood pressure seem modest (less than a 10–mm Hg reduction) for the magnitude of weight lost (30-50 kg). Nonsurgical methods of weight reduction (diet, exercise, appetite suppressants), typically practiced in subjects with lower BMI (25-39) than those in this study, produce modest weight loss (5-10 kg) but similar reductions in blood pressure (5-10 mm Hg).[9,10,22,23] With the substantial weight reductions after bariatric surgery, one might have anticipated larger drops in blood pressure than those actually seen, if body mass or fat mass is a key determinant of blood pressure.[4] However, a sizable portion of our subjects were normotensive before surgery and showed no or little reduction in blood pressure with a decline in body weight (Figure 3, black circles), while another portion were receiving active treatment for hypertension and thus also showed relatively modest reductions in blood pressure after surgery (Figure 2, open circles). When we examined just the subgroup of patients who appeared to have untreated hypertension before surgery, a decline in blood pressure at or above that seen with nonsurgical methods of weight reduction was found, ie, a 16–mm Hg decline in systolic blood pressure and a 7–mm Hg decline in diastolic blood pressure between the time of presurgical evaluation and 3 months after surgery. These changes were associated with a 10-kg decrease in body mass. Still, considerable further reductions in body weight then occurred out to postsurgical month 18, which were not accompanied by any notable additional reductions in blood pressure (see Figure 3). It would thus seem that reductions in body weight are not consistently predictive of reductions in blood pressure. However, once BMI had reached a plateau after surgery, it remained in the obese range, around 35 (Figure 1). The incidence of hypertension in individuals with a BMI of 30 or more, and of similar age to those studied herein, is as high as 46%[24] and may be higher.[1] Thus, from another perspective, it should not be surprising that a sizable fraction of our population (about 27%) were still hypertensive after surgery and substantial weight loss, since they were still obese. One might wonder whether the small size of this fraction, relative to that reported by others in epidemiologic studies,[1,24] might portend a gradual reemergence of hypertension in these patients, at least in those who underwent VBG, as predicted by the Sjöström et al findings.[12,25] Because of the obvious limitations of our study (retrospective, progressive loss of patients to follow-up), our data cannot answer this question.

In addition to the limitations of the present study just mentioned, a further possible limitation may be that blood pressure measurements were made once at each visit. The Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure[17] recommends that blood pressure measurements be made at least twice to verify accuracy. However, as also recommended by this committee, care was taken to ensure that patients were relaxed before measurements were made (see the "Methods" section). Also, the likelihood that our measurements were reasonably accurate, despite only a single measurement, is suggested by the facts that (1) the incidence of hypertension reported in this study is similar to that reported by others for very obese individuals[12,19-21]; (2) our detection of a significant number of individuals at initial evaluation who met the criteria for stage 1 hypertension, but were unaware of their condition, is not surprising (30% of the US population with hypertension is reportedly unaware their condition)[17]; and (3) the incidence of hypertension in our population sample at the conclusion of the study was similar to that in the general population.[26]

In conclusion, our findings are consistent with the notion that systolic and diastolic blood pressures improve when very obese individuals lose weight after bariatric surgery. The incidence of hypertension also declines, as reflected by the reduction in the number of individuals requiring antihypertensive medications to maintain a normal blood pressure and by the notable decline in systolic and diastolic blood pressures in subjects who had high blood pressure (stage 1 hypertension) but were unaware of it. However, the results cannot answer whether blood pressure and the incidence of hypertension ultimately return to presurgical levels; perhaps a future, prospective study will resolve this issue.

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