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The concept of obesity years: outcomes variation by age among patients with morbid obesity undergoing laparoscopic sleeve gastrectomy

Abstract

Background: A comprehensive analysis of BMI and obesity related comorbidities by age after laparoscopic sleeve gastrectomy (SLEEVE) has not been reported.

Objective: To identify variation in post-operative BMI and resolution of obesity comorbidities among age groups undergoing SLEEVE.

Methods: Data from 8,966 Surgical Review Corporation BOLD database adult patients who underwent SLEEVE was analyzed retrospectively in six age groups: <30(n=922), 30-40(n=2224), 40-50(n=2560), 50-60(n=2322), 60-70(n=816), and >70(n=52). Clinical information was collected at baseline and 12 and 24 months after SLEEVE. Data included Body Mass Index (BMI) and 30 weight-related comorbidities. Outcomes analysis was by ANOVA for continuous variables and general linear model for dichotomous variables, including baseline and post-operative data modified for binomial distribution.

Results: 12 months post-SLEEVE, BMI ranged from 33±7(60-70 years) to 35±6-9(40-50, 50-60, >70)($p<0.01$) and 35±7 to 36±9 at 24 months ($p<0.05$ only 30-40 v 60-70). Resolution of 12 weight related comorbidities was inversely proportional to age at 12 months post-operatively, while 4 resolved better in older patients. At 24 months post-operatively, diabetes mellitus, hypertension, hyperlipidemia, musculoskeletal pain and lower extremity edema persisted with increasing age ($p<0.05$, n=5).

Conclusion: Following SLEEVE, resolution of 12 weight-related medical problems was inversely proportional to age at 12 months. Key obesity comorbidities diabetes, hypertension, dyslipidemia, musculoskeletal pain and leg edema persisted directly proportional with increasing age through 24 months. Although the data here did not include date of obesity onset, these results suggest a concept of "obesity years" in which excess weight and comorbidities become entrenched in older patients who carry obesity the longest.

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Introduction

The prevalence of obesity continues to climb nationwide.[1] In this upsurge, all surgeons now must operate upon and manage patients with morbid obesity and its associated comorbidities such as hypertension, dyslipidemia obstructive sleep apnea and diabetes.[2] Laparoscopic sleeve gastrectomy (SLEEVE) has become one of the mainstays for the surgical treatment of obesity. Perioperative planning in this medically fragile population is paramount. Advance knowledge and clinical insight could facilitate patient selection and possibly reduce morbidity and mortality overall.

Older patients more often have multiple chronic comorbidities when compared with younger populations.[3,4] Ward and co-authors reported that the prevalence of adults with multiple chronic comorbidities increased from 21.8% in 2001 to 26% in 2010, correlating directly with increasing age.[3] There is, however, little data examining pre-operative age variation and persistence of these medical conditions within each age group following SLEEVE.

When patients with obesity are separated from the overall population, increasing age is associated with increased peri-operative morbidity and mortality following bariatric surgery.[5] Similar variation also has been exposed indirectly in previous studies comparing healthcare insurance status to weight related medical problems. Medicare patients with obesity, who tend to be older in age, have higher rates of almost all obesity-related medical problems, compared with Medicaid, private insurance and self-pay individuals.[6] However, since younger patients with obesity can be on Medicare because of disability, whether or not these findings place older patients at increased risk for persistence of weight-related medical problems after undergoing bariatric surgery is not clear from the published data.

Comparing patients less than 60 years old undergoing bariatric surgery with patients greater than 60, Kaplan and co-authors did not identify significant variation by age in the risk of peri-operative complications between those age groups.[7] However, pre-operative and post-operative variation through the range of age among patients undergoing bariatric surgery, and specifically among patients undergoing SLEEVE, is unknown. The objective of this investigation was to identify variation by decades of age in pre-operative clinical characteristics and in post-operative weight responses and resolution of obesity co-morbidities following SLEEVE in adults with obesity.

Materials and methods

With approval of the Surgical Review Corporation Data Access Committee and the Institutional Review Board (IRB) of Our

Lady Lourdes Medical Center, Camden, NJ, Bariatric Outcomes Longitudinal Database (BOLD), data from 8,966 adults patients who underwent SLEEVE between June 1, 2007 and December 31, 2010 was analyzed retrospectively at pre-operative baseline and at 12 and 24 months after SLEEVE in six age groups: <30 (n=922), 30-40 (n=2224), 40-50 (n=2560), 50-60 (n=2322), 60-70 (n=816) and >70 (n=52) years old.

Data on each patient included demographics, BMI and 31 obesity-related comorbidities, diagnosed according BOLD clinical definitions.[8] Prevalence of BMI and comorbid conditions was recorded pre-operatively and at 12 and 24 months after SLEEVE, including congestive heart failure (CHF), hypertension (HTN), angina, lower extremity edema (LEE), peripheral vascular disease (PVD), pulmonary hypertension (PHT), asthma, obstructive sleep apnea (OSA), obesity hypoventilation syndrome (OHS), abdominal hernia, cholelithiasis, gastroesophageal reflux disease (GERD), abdominal panniculitis, liver disease, urinary stress incontinence, back pain, impaired functional status, musculoskeletal pain, polycystic ovarian syndrome (PCOS), pseudotumor cerebri, diabetes mellitus (DM), gout, dyslipidemia (DLD), alcohol use, depression, mental health diagnosis, psychological impairment, substance abuse, tobacco use, and post-SLEEVE support group attendance.

Statistical analysis: Baseline differences by age were examined using t-test for continuous variables (weight, weight loss and BMI) and Chi-squared equation to examine association of age with categorical variables (co-morbidities). To identify post-SLEEVE variations by age for continuous values while adjusting for baseline value, a linear model was created with age and baseline value as factors, for each post-baseline time point. Pair-wise comparisons were examined using least squares means (baseline adjusted means) calculated from the model to find differences in the age groups while adjusting for baseline. The differences in obesity co-morbidities with age were examined by using a categorical model while adjusting for baseline co-morbidities in a similar fashion but using a more appropriate categorical model.[9]

Results

Preoperative and postoperative BMI and weight (kg) are presented in Table 1. At pre-SLEEVE baseline, weight and BMI varied inversely to increasing age, both highest at <30 years and lowest at >70 years (p<0.0001). The linear inverse variation of weight and BMI resolved 12 months post-SLEEVE. BMI ranged from 33±7 (60-70 years old) to 35±7 (40-50, 50-60, >70) (p<0.01) and 24 months post-SLEEVE 35±7 to 36±9 (p<0.05 only 30-40 v 60-70).

Table 1 Sleeve weight and BMI by age group

	BMI			Weight (kg)		
Age group	**Pre-Operative**	**12 Months**	**24 Months**	**Pre-Operative**	**12 Months**	**24 Months**
<30	48.2+/-8.1	33.2+/-8.7	35.6+/-6.2	135.6+/-27.9	93.8+/-27.0	96.8+/-18.7
30-40	47.3+/-8.1	34+/-10.1	34.8+/-12.5	132.8+/-28.2	98.3+/-33.0	98.3+/-33.6
40-50	46.6+/-8	35.2+/-9.3	34.5+/-9.6	130.7+/-27.3	100.1+/-29.6	99.4+/-33.4
50-60	46+/-7.5	34.6+/-7.7	35.5+/-7.5	127.8+/-25.2	96.8+/-23.9	99.6+/-25.1
60-70	45.3+/-7	33.4+/-6.8	36.1+/-9.4	125.3+/-23.2	93.9+/-22.6	97.7+/-31.1
>70	44.1+/-6.1	35.4+/-6.2	27.6*	122.6+/-21.4	97.9+/-23.1	87.1*
P value	<0.05	<0.05	NS	<0.05	<0.05, <40 v all	<0.05 <50 v >60

*BL, baseline (pre-operatively); 12, 12 months post-operatively; 24, 24 months post-operatively

BMI 12 months post-SG ranged from 33±7 (60-70 years old) to 35±6-9 (40-50, 50-60, >70) (p<0.01) and 24 months post-SG 35±7 to 36±9 (p<0.05 only 30-40 v 60-70) **At 24 months post-operatively, data was only available for one subject >70 years old

Pulmonary and cardiovascular obesity comorbidities by age are tabulated in Table 2. At preoperative baseline, all cardiovascular and pulmonary co-morbidities increased in incidence directly with increasing age except asthma, which was highest in the 50-60 and 60-70 year old age groups. At 12 months post-op, CHF, HTN, LEE, PHT, and OSA still increased directly with age (p<0.05), while at 24 months, only HTN and LEE varied directly with age (p<0.01).

Table 2 Sleeve pulmonary and cardiovascular comorbidities by age group

Sleeve pulmonary and cardiovascular comorbidities													
	CHF			**HTN**			**ANGINA**			**LEE**			**PVD**
	BL	**12**	**24**	**BL**	**12**	**24**	**BL**	**12**	**24**	**BL**	**12**	**24**	**BL**
<30	0.42	0	0	28.7	15.13	0	1.45	0	0	15.88	10.92	0	0.26
30-40	0.74	1.06	0	42.62	18.02	12.9	1.74	0.35	0	22.67	14.49	9.68	0.39
40-50	1.43	0.85	0	59.32	31.64	22.86	2.34	1.69	0	27.6	17.51	14.29	0.87
50-60	3.01	1.61	0	74.41	46.44	32.2	3.47	2.3	1.69	32.4	22.3	22.03	1.67
60-70	5.57	6.86	3.7	82.23	56.57	55.56	4.42	3.43	0	36.24	22.86	44.44	2.81
>70	6.58	0	0	84.81	56.25	100	3.64	0	0	35.62	25	100	3.36
P-Value	<0.0001	<0.0001	0.4032	<0.0001	<0.0001	0.0008	<0.0001	0.0855	0.8773	<0.0001	0.0126	0.0018	<0.0001

Abdominal and hepatobiliary obesity comorbidities by age are displayed in Table 3. All abdominal/hepatobiliary comorbidities varied directly with increasing age at preoperative baseline. Only abdominal hernia and stress urinary incontinence (SUI) varied directly with age at 12 months post-op (p<0.0001). Abdominal/hepatobiliary age variation resolved by 24 months post-SLEEVE.

Table 3 Sleeve abdominal and hepatobiliary comorbidities by age group

Sleeve abdominal and hepatobiliary comorbidities																		
	ABD hernia			Cholelithiasis			Gerd			Paniculitis			Liver disease			Stress incont.		
	BL	12	24	BL	12	24	BL	12	24	BL	12	24	BL	12	24	BL	12	24
<30	1.58	2.52	0	11.1	17.65	36.36	37.3	29.41	45.45	5.82	5.04	0	4.66	1.68	0	12.59	2.52	0
30-40	3.35	4.95	0	16.88	15.9	12.9	43.96	30.74	25.81	6.09	11.66	3.23	5.38	3.53	0	19.26	6.71	6.45
40-50	5.18	7.91	8.57	19.55	22.88	25.71	47.57	33.33	40	6.19	9.32	8.57	6.35	4.24	2.86	23.86	15.25	5.71
50-60	6.82	12.41	16.95	22.71	22.53	30.51	49.9	36.78	22.03	7.31	10.34	15.25	6.85	5.52	6.78	26.82	17.93	8.47
60-70	8.14	14.86	7.41	25.53	25.14	37.04	48.5	33.71	48.15	7.67	9.71	7.41	5.89	5.14	0	28.59	18.86	18.52
>70	7.42	25	0	24.28	18.75	0	44.44	25	100	6.09	6.25	0	3.99	0	0	30.65	18.75	0
P-Value	<0.0001	<0.0001	0.1189	<0.0001	0.1347	0.3377	<0.0001	0.4814	0.0665	<0.0001	0.462	0.3831	<0.0001	0.4248	0.4178	<0.0001	<0.0001	0.4043

*BL, baseline (pre-operatively); 12, 12 months post-operatively; 24, 24 months post-operatively

Endocrine and metabolic obesity comorbidities by age are listed in Table 4. Pre-operative diabetes, gout and dyslipidemia varied directly with increasing age. PCOS and pseudotumor cerebri varied inversely to age. Post -SLEEVE, diabetes and dyslipidemia varied directly by age through 12 and 24 months. PCOS varied inversely with age at 12 months.

Table 4 Sleeve Endocrine and Metabolic comorbidities by age group

Sleeve endocrine and metabolic comorbidities															
	DM			GOUT			HLD			PCOS			PTC		
	BL	12	24	BL	12	24	BL	12	24	BL	12	24	BL	12	24
<30	14.16	8.4	0	1.18	0	0	17.8	10.08	0	12.19	10.92	0	2.56	0.84	0
30-40	22.62	7.07	6.45	2.22	2.47	0	27.9	18.02	9.68	8.87	7.07	3.23	2.44	0	3.23
40-50	33.72	13.84	0	3.1	1.98	0	41.59	25.14	11.43	3.76	5.08	2.86	1.82	0.28	2.86
50-60	46.28	19.08	15.25	4.7	3.91	3.39	55.28	39.54	37.29	1.41	1.84	0	1.26	0.46	0
60-70	55.69	27.43	18.52	6.64	5.14	3.7	64.17	49.14	40.74	0.68	0.57	0	0.8	0	0
>70	57.66	25	100	8.19	6.25	0	64.73	37.5	100	0.35	0	0	0.49	0	0
P-Value	<0.0001	<0.0001	0.003	<0.0001	0.0782	0.7336	<0.0001	<0.0001	0.0005	<0.0001	<0.0001	0.6961	<0.0001	0.6899	0.6961

Psychological and behavioral obesity comorbidities by age are displayed in Table 5. Alcohol use, substance abuse and tobacco use varied inversely with increasing age (p<0.0001) at preoperative baseline. Baseline depression, mental health diagnosis and psychological impairment were highest in the 30-60 year old demographics. Mental health diagnosis, substance abuse and tobacco use all varied inversely with age at 12 months post-operatively (p<0.05).

Somatic obesity comorbidities by age post-operatively are resulted in Table 6. Back pain, musculoskeletal pain (MSP) and impaired functional status varied directly with age at preoperative baseline (p<0.0001). Back pain and functional impairment varied by age through 12 months (p<0.05) and musculoskeletal pain through 24 months (p<0.01). Overall, the baseline incidence of pre-operative weight and BMI and 21 obesity co-morbidities varied directly by increasing age; 7 varied inversely with increasing age. Resolution of 12 weight related comorbidities was inversely proportional to age at 12 months post-operatively, while 4 resolved better in older patients. DM, HTN, dyslipidemia, musculoskeletal pain and LEE persisted with increasing age at 24 months.

Table 6 Sleeve somatic comorbidities by age group

Sleeve somatic comorbidities									
	Back pain			Impaired function			MSK pain		
	BL	12	24	BL	12	24	BL	12	24
<30	43.28	21.01	18.18	0.63	0.84	9.09	29.88	16.81	9.09
30-40	46.33	30.74	22.58	1.04	0.71	0	36.32	20.14	3.23

Table Continued...

Sleeve somatic comorbidities									
	Back pain			**Impaired function**			**MSK pain**		
	BL	**12**	**24**	**BL**	**12**	**24**	**BL**	**12**	**24**
40-50	47.3	29.38	31.43	2.35	2.26	2.86	42.82	24.58	28.57
50-60	49.27	36.55	42.37	4.46	2.99	6.78	49.99	36.55	40.68
60-70	51.51	30.86	33.33	7.61	6.29	11.11	53.34	35.43	37.04
>70	50.73	37.5	100	9.8	0	0	53.88	43.75	100
P-Value	<0.0001	0.0305	0.2243	<0.0001	0.0066	0.4884	<0.0001	<0.0001	0.0016

*BL, baseline (pre-opeeratively); 12, 12 months post-operatively; 24, 24 months post-operatively

Discussion

The results of this investigation identify clinically significant variations by decade of age in weight, BMI, and weight-related medical problems pre-SLEEVE, many of the most serious conditions varing directly with increasing age up to 24 months post-operatively. At baseline, the incidence of cardiopulmonary obesity co-morbidities CHF, HTN, angina, PVD, PHT, OSA, OHS, and LEE increased directly with increasing patient age. Abdominal/hepatobiliary co-morbidities hernia, cholelithiasis, panniculitis, and SUI increased directly with age. Endocrine/metabolic problems diabetes, gout, and dyslipidemia increased directly with age, while PCOS and pseudotumor cerebri correlated inversely with age. Somatic conditions back pain, MSP and impaired functional status increased directly with age. Pre-operative mental health diagnosis was inverse to age, psychological impairment direct with age, and depression and psychological impairment highest in the 30-60 age groups. Baseline alcohol, tobacco and substance abuse all varied inversely with age. Asthma, GERD, liver disease, and depression were highest in the 50-70 age cohorts.[10] At 12 months post-SLEEVE, CHF, HTN, PHT, OSA, LEE, hernia, SUI, diabetes, dyslipidemia, back pain, MSP, and impaired function still varied directly with age, while PCOS, mental health diagnosis and alcohol/tobacco/substance abuse correlated inversely with age. By 24 months only HTN, LEE, diabetes, dyslipidemia, MSP and impaired function varied directly with age, and PCOS and alcohol abuse varied inversely. Although the years each patient had endured obesity was not captured in BOLD, from these results one might speculate on the concept of obesity years, wherein the longer one has obesity, the more severe and entrenched become weight-related medical problems, many of which do not resolve with post-SLEEVE weight loss. This advance knowledge may guide patient evaluation and preparation for SLEEVE, possibly improving short and long-term outcomes. Our review of the literature indicates that these variations by decades of age in pre-operative clinical characteristics and SLEEVE outcomes have not been reported previously and are significant findings of this study.

Before understanding how age can impact the prevalence of many common obesity related comorbidities, it is first important to know how these comorbidities vary between the general and obese populations. For example, the incidences of hypertension, diabetes, dyslipidemia and metabolic syndrome increases with increasing body mass index.[2] The dense capillary network that forms with adipose tissue and the high metabolic demand it requires place a large hemodynamic repercussion from obesity that stresses the heart over time.[11] Both total blood volume and cardiac output increase with increasing adipose which can lead to increased left ventricular wall stress and eventual hypertrophy. In cases of long-standing obesity, cardiomyopathy, congestive heart failure and even cardiac related death can result.[12]

A significant finding of the present investigation is the pre-operative variation directly with increasing age of CHF, HTN, angina, PVD, PHT, OSA, OHS and LEE, in patients with obesity. This direct variation persists post-SLEEVE in CHF, HTN, LEE, PHT and OSA at 12 months and HTN and LEE at 24 months, despite successful weight loss and clinically similar BMI across all age groups. From these results, one might speculate that the older individuals are before undergoing SLEEVE, the less likely they are to resolve serious cardiovascular and pulmonary weight-related sequelae.

The data presented here confirms previous results and expands on them in the interaction of age with abdominal/hepatobiliary problems of obesity. At baseline, both women and men with obesity have increased rates of abdominal hernias, cholelithiasis, GERD, panniculitis, liver disease and SUI.[13–16] In the present report these conditions not only affected high percentages of patients with obesity, but, in addition, GERD, liver disease, hernia, cholelithiasis, panniculitis and SUI varied by age, the latter three increasing directly with age. These variations by age in abdominal and hepatobiliary obesity co-morbidities disappeared by 24 months post-SLEEVE. Therefore, pre-operative findings notwithstanding, these results indicate that age and the duration of obesity do not impair the ability of post-sleeve weight loss to resolve abdominal/hepatobiliary comorbidities.

Diabetes, gout and dyslipidemia all increased directly with increasing age in preoperative SLEEVE patients. Many studies describe the direct correlations between prevalence of diabetes, gout and dyslipidemia with age and, separately, with obesity.[17–20] Our review of the literature indicates that this variation by decades of age in rates of endocrine and metabolic problems specifically among patients with obesity have not been reported previously and are important findings of this investigation. The further identification of continued variation directly by age of diabetes and dyslipidemia 24 months post-SLEEVE is new advance knowledge contributing to the surgical treatment of obesity among older patients. Persistent diabetes and dyslipidemia by age adds perspective to Buchwald's observation that 76.8% of individuals undergoing bariatric surgery resolved diabetes, and dyslipidemia improved in 70%.[21] While malabsorptive procedures, such as Roux-en-Y gastric bypass and biliopancreatic diversion/duodenal switch, achieved promising long term results in diabetes resolution compared with restrictive procedures, such as SLEEVE, age was not addressed.[22–25]

From a biomechanical perspective, obesity is one of the most important risk factors for musculoskeletal disease.[26,27] Not only does increasing BMI increase risk of musculoskeletal pain and other somatic problems, but individuals with obesity also are less likely to resolve these symptoms.[28] The data reported in the present investigation demonstrated that back pain, MSP and impaired functional status varied directly with increasing age, with this relationship persisting

24 months post-SLEEVE for MSP and impaired functional status. From these results one can speculate that the musculoskeletal damage from obesity becomes more irreversible with increasing age of the SLEEVE patient.

Conversely, pseudotumor cerebri, PCOS, tobacco use, substance abuse and mental health diagnosis were more prevalent in younger patients, varying inversely with increasing age at baseline, and the latter four also in post-SLEEVE follow-up. Three of the four are psychological/behavioral related comorbidities that naturally occur more frequently in younger individuals. Gott reported poor resolution of psychological/behavioral co-morbidities in bariatric surgery patients.[29] Most mental health and substance use disorders are diagnosed in childhood/adolescence.[30] PCOS is a genetic disorder that is usually discovered when an individual is trying to become pregnant, thus explaining why it is more common in younger women.[31]

Weight and BMI varied inversely with increasing age at both pre-operative baseline and in follow-up post-operatively. However, in spite of statistically and clinically significant lower BMI pre-SLEEVE with increasing age, the incidence of most obesity co-morbidities still varied directly with age. At 12 and 24 months following SLEEVE, BMI in all age decades fell to 35 or lower, and yet serious obesity co-morbidities persisted at rates directly proportional to increasing age. These results indicate that BMI was not a causative factor in the direct and inverse variation by age of weight-related medical problems among SLEEVE patients in this investigation.

There were several limitations to our study. This is a retrospective analysis of prospectively collected data, and, as such, carries the typical associated confounders. In addition, the patients in this study represent a self-selected population who chose SLEEVE and therefore the findings might not be applicable to other bariatric procedures. Diagnosis of co-morbidities was based on a clinical diagnosis as defined in BOLD, rather than derived from a pathological diagnosis.[8] For example, liver biopsy was not required for BOLD, so liver disease was diagnosed by clinical criteria. Lastly, although the length of time each patient endured obesity prior to undergoing SLEEVE was not recorded in BOLD, from these results one might speculate on the concept of obesity years, wherein the longer a patient carries the excess weight of obesity and its physical and metabolic consequences, the more severe and entrenched weight related medical problems become, possibly diminishing the benefits of SLEEVE for older patients.

Conclusion

Among SLEEVE patients, pre-operatively weight, BMI, and 29 weight-related medical problems varied significantly by age. However, 12 and 24 months after SLEEVE minimal but statistically significant BMI variation by age was not clinically important. Nevertheless, resolution of 12 weight-related co-morbidities was inversely proportional to age at 12 months, while four others resolved better in older patients. The key serious co-morbidities diabetes, hypertension, dyslipidemia, musculoskeletal pain, and leg edema did not resolve as well in older SLEEVE patients compared with younger individuals, and they remained increased with advancing age up to 24 months post-operatively. These results suggest the concept of "obesity years" in which obesity co-morbidities become entrenched in older patients who were obese the longest. One might speculate that this advance knowledge could facilitate patient selection for SLEEVE and encourage an increased index of suspicion in bariatric surgeons for serious pre-operative problems among older patients, and possibly facilitate expectant peri-operative management in those high-risk patients. The advance knowledge presented here also can supplement clinical judgement for non-bariatric surgeons when confronted by patients with obesity.

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Conflicts of interest

The authors declare that they have no competing interests.

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