Surgically induced weight loss, including reduction in waist circumference, is associated with improved pulmonary function in obese patients

Yu-Feng Wei, M.D.\textsuperscript{a}, Wei-Kung Tseng, M.D.\textsuperscript{a}, Chih-Kun Huang, M.D.\textsuperscript{b}, Chi-Ming Tai, M.D.\textsuperscript{a}, Chin-Feng Hsuan, M.D.\textsuperscript{a}, Huey-Dong Wu, M.D.\textsuperscript{c,\ast}

\textsuperscript{a}Department of Internal Medicine, E-Da Hospital, I-Shou University, Kaohsiung County, Taiwan
\textsuperscript{b}Department of Surgery, E-Da Hospital, I-Shou University, Kaohsiung County, Taiwan
\textsuperscript{c}Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan

Abstract

Background: Obesity is associated with impaired pulmonary function. We evaluated the effect of bariatric surgery on pulmonary function among obese patients and identified potential anthropometric factors of obesity corresponding to the reversal of impaired pulmonary function.

Methods: Pulmonary function and anthropometric factors were studied in 94 obese patients aged 18–65 years with a body mass index $\geq 32$ kg/m\textsuperscript{2}. Pulmonary function tests were performed preoperatively and 3 months after bariatric surgery. The measurements included forced vital capacity (FVC), forced expiratory volume in the first second (FEV\textsubscript{1}), total lung capacity, expiratory reserve volume, residual volume, and diffusing capacity of the lung for carbon monoxide. The anthropometric factors included the body weight, body mass index, waist circumference (WC), hip circumference, waist/height ratio, and waist/hip ratio. The changes in anthropometric parameters were analyzed in relation to pulmonary function test results. Multiple linear regression models were applied to identify the factors that influenced pulmonary function after bariatric surgery.

Results: When measured 3 months after surgery, all anthropometric parameters for the 94 patients studied had significantly decreased, and the pulmonary function test parameters had significantly improved. Of the anthropometric parameters, the reduction in body weight, WC, and waist/height ratio correlated significantly with increases in the FEV\textsubscript{1} and FVC. In the multiple linear regression analysis, only the reduction in WC correlated significantly with the reductions in the FEV\textsubscript{1} and FVC.

Conclusion: After bariatric surgery, all anthropometric parameters of obesity decreased significantly and the pulmonary function improved. This improvement correlated best with the reduction in the WC and perhaps a decreased intra-abdominal pressure. (Surg Obes Relat Dis 2011;7:599–604.) © 2011 American Society for Metabolic and Bariatric Surgery. All rights reserved.

Keywords: Bariatric surgery; Obesity; Pulmonary function test; Waist circumference

Obesity increases the risk of metabolic disorders, cardiovascular diseases, diabetes, cancer, and pulmonary dysfunction [1,2]. Increasing evidence has demonstrated the negative effects of obesity on the respiratory system. Obesity can cause conditions such as obstructive sleep apnea, obesity hypventilation syndrome, and obstructive airway disease [3,4]. The results from our previous cross-sectional study revealed that all the anthropometric parameters of obesity, including body weight (BW), body mass index (BMI), waist circumference (WC), waist/hip ratio (WHR), waist/height ratio (WHtR), and hip circumference (HC), were associated...
with a restrictive pattern of impaired pulmonary function in obese Chinese adults in Taiwan [5]. Of these parameters, the WC had the greatest effect on pulmonary function.

Many studies have demonstrated that weight reduction, either by dietary modification or surgical intervention, leads to improvements in various organ functions [6–8]. Bariatric surgery, with the dual mechanisms of gastric volume restriction and malabsorption, is recommended with increasing frequency for the treatment of the morbidly obese [9,10]. Effective weight loss after surgery could improve the entire cluster of cardiovascular disease risk factors, including diabetes, hyperlipidemia, hypertension, atherosclerosis, inflammation, obesity hypoventilation syndrome, and obstructive sleep apnea [6,11–14]. The surgical treatment of morbid obesity is also associated with a significant improvement in pulmonary function [15–20]. However, no data are available regarding the relationship between alterations in pulmonary function and weight reduction after bariatric surgery in an Asian-Pacific population. In addition, the anthropometric parameter of obesity, the most important determinant of pulmonary function improvement after bariatric surgery, has not been examined.

The aims of the present longitudinal study were to evaluate the changes in pulmonary function in obese Chinese patients before and after bariatric surgery; and to document the changes in various anthropometric measurements of obesity, including the BW, BMI, WC, HC, WHtR, and WHR, to identify the potential factors that might correlate with the reversal of pulmonary function impairment.

Methods

Study population

We evaluated patients aged 18–65 years who had a BMI >37 kg/m² or a BMI of 32–37 kg/m² with obesity-related co-morbidities. The patients who underwent bariatric surgery at the international endoscopic obesity center of the E-Da Hospital in Southern Taiwan from July 2007 to December 2008 were enrolled in the present study. All obese patients received the same modality of bariatric surgery (laparoscopic Roux-en-Y gastric bypass), and the surgical procedure has been previously described in full [10]. The patients who participated in our previous study were also included [5]. The inclusion criteria were adopted from a modification of the recommendations of the Asian-Pacific consensus [21]. Patients were excluded if they had 1 of the following conditions: a history of chronic or active lung disease, pregnancy, endocrinopathy-induced obesity, or malignancy. All patients provided written informed consent before joining the study and before surgery. The Human Ethics Committee of our institution approved the study protocol.

Measurements of anthropometric parameters of obesity

All patients were examined for various anthropometric parameters of obesity at enrollment (baseline) and 3 months after surgery (follow-up). The BW (in kilograms) and height (in meters) were measured after an overnight fast. The BMI was calculated as the weight divided by height in square meters. A D-loop nonstretch fiber glass tape was used for the WC and HC measurements. The WC was measured around the abdomen on the midpoint between the lower border of the rib cage and the iliac crest with the patient standing, their abdomen relaxed, both feet touching, and their arms hanging freely, at the end of normal expiration. In patients without a natural waistline, the measurement was taken at the level of the umbilicus [22]. The HC was measured at the maximal circumference between the iliac crest and the crotch with the patient standing. The WHR and WHtR was defined as the WC/body height and WC/HC, respectively.

Pulmonary function testing

Patients participating in the present study underwent pulmonary function tests (PFTs) before and 3 months after bariatric surgery. The PFTs were performed using a body plethysmography (Vmax 229, SensorMedics, Yorba Linda, CA), and all tests were performed by the same team of technicians according to the recommendations of the American Thoracic Society/European Respiratory Society [23]. The reference equations from Knudson et al. [24] were used to express the predicted values of the PFTs. Each participant performed ≥3 tests (with ≥2 reproducible and acceptable maneuvers) in a sitting position, with nose clips in place. The measurements included the forced vital capacity (FVC), forced expiratory volume in first second (FEV₁), expiratory reserve volume, residual volume, and total lung capacity. The results were considered reproducible if the second highest FEV₁ and FVC values were within 5% of the highest values. The highest measured FEV₁ value and the corresponding FVC value were coded for computer analysis. The diffusing capacity of the lung for carbon monoxide (DLCO) was measured using the single breath technique, and the measured values were corrected for the hemoglobin concentration. The results of these tests are expressed as the percentages of the predicted normal values.

Statistical analysis

The statistical analyses were performed using the commercially available statistical software package, Statistical Package for Social Sciences, version 17 (SPSS, Chicago, IL). The continuous parameters are presented as the mean ± SD and categorical parameters as numbers and percentages. Paired t tests were used to compare the baseline and follow-up parameters. Pearson’s correlation coefficients were calculated to assess the relationship between changes in the various anthropometric measurements of obesity and the
PFT parameters after surgery. Multiple regression analyses were performed to determine which anthropometric parameters were the determinants for the changes in pulmonary function after surgery. The various PFT parameters were the dependent variables, and age, gender, smoking history, and reduction in BW (dBW), BMI (dBMI), WC (dWC), HC (dHtR), WHtR (dWHtR), and WHR (dWHR) were included as the independent determinant variables. A stepwise strategy was applied to select the significant independent variables, with $P < .05$ as the inclusion criterion.

Results

Participant characteristics

From July 2007 to December 2008, 139 consecutive obese Chinese patients underwent bariatric surgery at the obesity center of E-Da Hospital in Southern Taiwan. Of these 139 patients, 30 were excluded because of incomplete PFTs during follow-up and 15 because of inadequate performance of the PFTs at baseline or follow-up. Of the 94 participants, women were predominant (62%), and the age range was 18–59 years (mean 31.2 ± 9.8). A history of smoking was noted in 26% of the patients. None of the patients quit smoking during the study period.

Anthropometric parameters of obesity and PFT

The various anthropometric parameters of obesity measured before and 3 months after bariatric surgery, including BW, BMI, WC, HC, WHtR, and WHR, are summarized in Table 1. All the anthropometric parameters were significantly reduced ($P < .05$) 3 months after surgery.

The PFT findings are summarized in Table 2. All PFT values had improved significantly ($P < .05$) 3 months after bariatric surgery. On average, each kilogram of BW reduction was associated with an improvement of .28% (9.4 mL) in FEV$_1$ and .23% (9.1 mL) in FVC. In addition, for each 1 kg/m$^2$ decrease in the BMI, the FEV$_1$ and FVC value increased by .77% (25.7 mL) and .63% (24.8 mL), respectively. Finally, for each centimeter of WC reduction, the FEV$_1$ and FVC increased by .44% (14.8 mL) and .36% (14.3 mL), respectively.

Relationship between reduction in anthropometric parameters of obesity and improvement in pulmonary function

Pearson’s correlation coefficients were calculated to assess the relationship between the reduction in the various anthropometric parameters of obesity and improvements in the PFT parameters after bariatric surgery. The reductions in BW (dBW), WC (dWC), and WHtR (dWHtR) correlated positively and significantly with the improvements in FVC (dFVC) and FEV$_1$ (dFEV$_1$) (Table 3). More significant relationships were detected between dWC and dFEV$_1$ ($r =$ .238, $P = .021$), and dFVC ($r =$ .249, $P = .015$) than with the other anthropometric parameters measured (Fig. 1). DLCO significantly increased as the BW, BMI, WC, and

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**Table 1**

<table>
<thead>
<tr>
<th>Anthropometric parameter</th>
<th>Before surgery</th>
<th>After surgery</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>119.3 ± 20.3 (78–193)</td>
<td>98.5 ± 20.2 (63.7–151)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.6 ± 7.5 (149–183)</td>
<td>165.7 ± 7.4 (149.3–183)</td>
<td>.99</td>
</tr>
<tr>
<td>Body mass index (kg/m$^2$)</td>
<td>43.4 ± 7.3 (32.9–66.7)</td>
<td>35.8 ± 6.5 (25.4–55)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>122.6 ± 15.1 (92–177)</td>
<td>109.4 ± 13.7 (80–147)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hip circumference (cm)</td>
<td>130.1 ± 13.7 (104–177)</td>
<td>118.8 ± 12.4 (94–157)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Waist/height ratio</td>
<td>.74 ± .09 (.60–1.02)</td>
<td>.66 ± .08 (.51–.88)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Waist/hip ratio</td>
<td>.94 ± .08 (.77–1.45)</td>
<td>.92 ± .08 (.69–1.09)</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD, with ranges in parentheses.

**Table 2**

<table>
<thead>
<tr>
<th>Pulmonary function parameter</th>
<th>Before surgery</th>
<th>After surgery</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV$_1$ (% predicted)</td>
<td>91.8 ± 15.3 (59–132)</td>
<td>97.7 ± 13.7 (64–125)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>92.8 ± 15.0 (57–131)</td>
<td>97.6 ± 13.4 (65–125)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>FEV$_1$/FVC</td>
<td>84.1 ± 4.5 (74–93)</td>
<td>85.1 ± 4.3 (74–98)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>TLC (% predicted)</td>
<td>80.6 ± 11.7 (53–106)</td>
<td>87.5 ± 18.5 (53–116)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>RV (% predicted)</td>
<td>73.1 ± 20.2 (49–113)</td>
<td>78.5 ± 20.8 (50–123)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>ERV (% predicted)</td>
<td>77.3 ± 22.3 (21–129)</td>
<td>79.7 ± 28.1 (22–137)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>DLCO (% predicted)</td>
<td>80.5 ± 16.5 (49–133)</td>
<td>87.6 ± 18.7 (53–136)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

$FEV_1$ = forced expiratory volume in first second; $FVC$ = forced vital capacity; $TLC$ = total lung capacity; $RV$ = residual volume; $ERV$ = expiratory reserve volume; $DLCO$ = diffusing capacity of lung for carbon monoxide.

Data presented as mean ± SD, with ranges in parentheses.
HC decreased. However, the dWHR had no significant correlation with the parameters of PFT measured in our study. None of the changes in the anthropometric parameters correlated significantly with the change in the FEV1/FVC.

Multiple linear regression analysis of anthropometric and PFT parameters

Multiple linear regression analysis of the anthropometric and PFT parameters was performed, and these measurements were adjusted for potential confounding factors, such as age, gender, and smoking history. Only dWC was found to be an independent determinant of dFEV1 and dFVC, and dBW was a determinant of dDLCO.

Discussion

The major finding of the present study was that all the anthropometric parameters of obesity, including BW, BMI, WC, HC, WHtR, and WHR, were significantly reduced 3 months after bariatric surgery. The PFT parameters also improved significantly. After adjustment for potential confounding factors, such as age, gender, and smoking history, dWC correlated with dFEV1 and dFVC, and dBW correlated with dDLCO. These results indicate that pulmonary function can be improved after bariatric surgery in obese Chinese adults in Taiwan. The reduction in the WC was the determinant for the reversal of impaired pulmonary function. To the best of our knowledge, this is the first study to examine the relationship between the improvement of pulmonary function and weight reduction after bariatric surgery in an Asian-Pacific population.

A longitudinal study suggested that a restrictive pattern assessed with a single spirometric test was associated with increased morbidity and mortality [25]. Obesity can profoundly impair pulmonary function and diminish exercise capacity because of its adverse effects on respiratory mechanics, respiratory muscle strength, lung volume, work of breathing, and gas exchange [3]. These aspects of impaired pulmonary function can result from the increased abdominal load that alters chest wall mechanics [26,27]. Sugerman et al. [28,29] reported that central obesity increases the intra-abdominal pressure, which increases the pleural pressure, cardiac filling pressure, and intrathoracic pressure. In addition, an increased abdominal pressure correlated highly with the WC or sagittal abdominal diameter ($r = .74$, $r = .78$), and was primarily responsible for obesity hypoventilation owing to elevation of the diaphragm and a restrictive, rather than obstructive, pulmonary dysfunction [26]. Furthermore, an increasing number of studies have supported the concept that abdominal fat deposition, often indicated by the WC,

Table 3 Correlations between changes in anthropometric parameters of obesity and pulmonary function parameters

<table>
<thead>
<tr>
<th>Pulmonary function parameter</th>
<th>Anthropometric parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>dFEV1 (%)</td>
<td>dBW .21* dBMI .19 dWC .24* dHC .13 dWHR .22* dWHR .19</td>
</tr>
<tr>
<td>dFVC (%)</td>
<td>dBW .22* dBMI .22* dWC .25* dHC .16 dWHR .23* dBW .17</td>
</tr>
<tr>
<td>dFEV1/FVC (%)</td>
<td>dBW .15 dBMI .11 dWC .09 dHC .01 dWHR .08 dBW .09</td>
</tr>
<tr>
<td>dTLC (%)</td>
<td>dBW .07 dBMI .12 dWC .18 dHC .17 dWHR .19 dBW .08</td>
</tr>
<tr>
<td>dRV (%)</td>
<td>dBW .02 dBMI .05 dWC .02 dHC .07 dWHR .03 dBW .09</td>
</tr>
<tr>
<td>dERV (%)</td>
<td>dBW .28† dBMI .27* dWC .05 dHC .04 dWHR .05 dBW .05</td>
</tr>
<tr>
<td>dDLCO (%)</td>
<td>dBW .46† dBMI .44† dWC .29† dHC .23* dWHR .14 dBW .02</td>
</tr>
</tbody>
</table>

$d = \text{change in parameter}; \text{BW} = \text{body weight}; \text{BMI} = \text{body mass index}; \text{WC} = \text{waist circumference}; \text{HC} = \text{hip circumference}; \text{WHtR} = \text{waist/height ratio}; \text{WHR} = \text{waist/hip ratio}; \text{FEV}1 = \text{forced expiratory volume in first second}; \text{FVC} = \text{forced vital capacity}; \text{TLC} = \text{total lung capacity}; \text{RV} = \text{residual volume}; \text{ERV} = \text{expiratory reserve volume}; \text{DLCO} = \text{diffusing capacity of lung for carbon monoxide}.

Data presented as Pearson’s correlation coefficients.

* $P < .05$

† $P < .01$

Fig. 1. dWC correlated positively with (A) dFEV1 and (B) dFVC in obese Chinese patients who underwent bariatric surgery.
WHR, or WHtR, are better predictors of pulmonary function impairment than the BMI [5,30–33]. The findings from previous studies in Canada and the United Kingdom have also revealed that the WC is significantly associated with decreased FEV₁ and FVC [33,34]. Their findings are consistent with those from our previous study that the WC is more predictive of pulmonary function impairment [5].

Sugerman et al. [12–14] reported that weight loss after gastric bypass decreased the abdominal pressure, sagittal abdominal diameter, and obesity-related co-morbidities, including obesity hypoventilation and sleep apnea syndrome. Several studies have also demonstrated that pulmonary function can be improved after weight loss surgery [15–20]. Dávila-Cervantes et al. [16] described 30 patients with improved FEV₁ (89–103%) and FVC (84–97.5%) 1 year after vertical banded gastroplasty. Two later studies reported similar results [17,18]. In a study by Santana et al. [19], significant improvement in both FVC and FEV₁ was found in 39 patients who underwent weight loss surgery, with the improvement in pulmonary function more pronounced in severely morbidly obese patients (BMI ≥60 kg/m²) than in less morbidly obese patients (BMI 40–59.9 kg/m²). Recently, Nguyen et al. [20] examined the pulmonary function of 104 morbidly obese patients who underwent either laparoscopic gastric bypass or gastric banding. They reported that weight loss after surgery significantly improved the restrictive and obstructive respiratory mechanics associated with obesity [20]. These improvements were observed as early as 3 months postoperatively. However, they did not identify the component of obesity that had the most influence on pulmonary function after weight reduction. In the present study, we found that a reduction in WC was the possible determinant of the reversal of pulmonary function impairment in obese Chinese patients in Taiwan.

Sekhri et al. [35] emphasized the potential role that factors, such as age and gender, have on obesity and pulmonary function. These results can be explained by the observations that abdominal obesity tends to increase with age and also that body fat is distributed differently in men and women [36,37]. In the present study, when we adjusted for the potential confounders of age, gender, and smoking history, a reduction in WC was the only parameter that significantly correlated with pulmonary function improvement, especially improvements in FEV₁ and FVC.

The effect of obesity on the change in DLCO is heterogeneous, and the exact pathophysiologic mechanism leading to changes in DLCO is not clear. Obese patients without clinically apparent heart disease can have a high output state and elevated total and central blood volumes, which will increase the capillary blood volume and thereby cause elevations in DLCO [38]. However, a reduced DLCO can also be found in obese individuals and might reflect a structural change in the interstitium of the lung, resulting from lipid deposition, cellular hyperplasia, alveolar enlargement, and/or a decreased alveolar surface area [3,39]. In a previous study, DLCO was found to improve after bariatric surgery, and this improvement was strongly associated with changes in alveolar volume and the WHR [40]. However, in the present study, DLCO significantly increased as the BW, BMI, WC, and HC decreased. After adjusting for confounding factors, the decrease in BW was the only parameter that correlated positively with an increase in DLCO.

The present study had some inherent limitations. First, all PFTs were expressed as the percentage of the predicted value rather than the actual value as the outcome in our analyses. Our reference equations were not for an Asian-based population; however, we documented that the changes in the PFT results within 1 individual could minimize this variation. Second, the analyses used in the present study were limited to those patients who underwent a bariatric surgery evaluation. A follow-up rate of 76% (94 of 124) might have led to a selection bias, although we adjusted for some potential confounding factors. Finally, we only evaluated the pulmonary function at baseline and 3 months after surgery, although previous studies have reported significant improvements in lung function from 3 months to 1 year after surgery. A long-term follow-up study might be necessary to determine whether the improved pulmonary function and decreased anthropometric parameters are maintained beyond the period of our study.

Conclusion

Just as in previous studies, surgically induced weight loss was associated with improved pulmonary function. Through careful analysis of the relationship between the changes in the anthropometric parameters and the changes in PFT parameters, this improvement correlated best with a decreased WC and perhaps a decreased intra-abdominal pressure.

Acknowledgment

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Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

References


