**Background:** Bariatric surgery has emerged as the most effective treatment for class III obesity (body mass index, ≥40). The number of operations continues to increase. We measured case fatality and death rates by time since operation, sex, age, specific causes of death, and mortality rates.

**Design and Setting:** Data on all bariatric operations performed on Pennsylvania residents between January 1, 1995, and December 31, 2004, were obtained from the Pennsylvania Health Care Cost and Containment Council. Matching mortality data were obtained from the Division of Vital Records, Pennsylvania State Department of Health.

**Outcome Measures:** Age- and sex-specific death rates after bariatric surgery.

**Results:** There were 440 deaths after 16,683 operations (2.6%). Age-specific death rates were much higher in men than in women and increased with age. Age- and sex-specific death rates after bariatric surgery were substantially higher than comparable rates for the age- and sex-matched Pennsylvania population. The 1-year case fatality rate was approximately 1% and nearly 6% at 5 years. Less than 1% of deaths occurred within the first 30 days. Fatality increased substantially with age (especially among those >65 years), with little evidence of change over time. Coronary heart disease was the leading cause of death overall, being cited as the cause of death in 76 patients (19.2%). Therapeutic complications accounted for 38 of 150 natural deaths within the first 30 days, including pulmonary embolism in 31 (20.7%), coronary heart disease in 26 (17.3%), and sepsis in 17 (11.3%).

**Conclusions:** There was a substantial excess of deaths owing to suicide and coronary heart disease. Careful monitoring of bariatric surgical procedures and more intense follow-up could likely reduce the long-term case fatality rate in this patient population.

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**HE PREVALENCE OF CLASS III obesity (body mass index [calculated as weight in kilograms divided by height in meters squared], ≥40) has increased substantially in the United States.**

**See Invited Critique at end of article**

A follow-up study of patients at McGill University in Montreal, Quebec, from 1986 to 2002 evaluated hospitalizations before and after gastric bypass surgery in California from 1995 through 2004 and reported a high percentage of readmissions during the 3-year follow-up, usually for obesity-related conditions.
In the present study, we have identified all bariatric operations for Pennsylvania residents from January 1, 1995, through December 31, 2004 (n = 16,683), performed in Pennsylvania. It is likely that almost all Pennsylvania residents to the present have undergone their bariatric surgical procedures within the state because of the large number of facilities in Pennsylvania performing bariatric surgery, including major research centers. We measured case fatality and death rates by time since bariatric surgery, sex, and age and the specific causes of death and mortality rates in relation to comparable death rates among Pennsylvania residents. Patients were followed up for a maximum of 9 years (1995-2004).

METHODS

Data were obtained from the following 2 databases: (1) the Pennsylvania Health Care Cost and Containment Council database,10,11 to identify patients hospitalized for bariatric surgery, and (2) the Division of Vital Records, Pennsylvania State Department of Health, to determine deaths and obtain copies of death certificates.

The Pennsylvania Health Care Cost and Containment Council collects data in the state of Pennsylvania, including all hospital discharges and ambulatory patient procedure records each year from hospitals and freestanding ambulatory surgery centers. The hospitals and freestanding surgery centers are required by law to electronically submit quarterly administrative data for all in-patient discharges and select specified ambulatory/outpatient procedures within 90 days after the end of a quarter.

All state-resident patients who underwent bariatric surgery in Pennsylvania were identified in the Pennsylvania Health Care Cost and Containment Council database. Each study subject fulfilled the following criteria: all in-patient discharges with International Classification of Diseases, Ninth Revision, Clinical Modification, diagnosis codes of 278.00 (obesity, unspecified) or 278.01 (morbid obesity); and all in-patient discharges with major diagnostic group code 10 and diagnostic related group code 288 (operative procedures for obesity).

The following variables were collated for each patient: (1) age of the patient at surgery, (2) sex of the patient, (3) race of the patient, (4) date and year of surgery, (5) hospital where the surgery was performed, (6) county where the surgery was performed, and (7) primary operating surgeon.

The specific diagnoses were reviewed, as well as the comorbid conditions from the hospital record before entry into the database to exclude miscoded records.

After identification of the patient cohort, the data were directly matched with the database of the Division of Vital Records, Pennsylvania State Department of Health, using the Social Security number of patients in addition to age and sex. The matching was performed directly between the staffs of the Pennsylvania Health Care Cost and Containment Council and the Division of Vital Records. A positive match would occur only if a patient had died and the death certificate was archived by the Division of Vital Records. A negative match was performed directly between the staffs of the Pennsylvania Health Care Cost and Containment Council database to exclude miscoded records.

RESULTS

There were 16,683 bariatric surgery procedures performed in Pennsylvania between January 1, 1995, and December 31, 2004, on 29,493 men (17.7%), including 179 black men (1.1%), and 13,734 women (82.3%), including 1,501 black women (9.0%), who were residents of...
Pennsylvania at the time of the operation (Table 1 and Table 2). Although 32 bariatric surgical procedures were identified in 1995, 3818 bariatric surgical procedures were performed in 2004 (Table 1). The mean age of patients at the time of bariatric surgery was 48 years (median age, 49 years). The estimated incidence of bariatric surgery by age, determined by using the mean number of bariatric operations in 2003 and 2004 as the numerator and the population in Pennsylvania in 2003 as the denominator, was 97 per 100 000 for those aged 25 to 34 years; 116 per 100 000 for those aged 35 to 44 years; 119 per 100 000 for those aged 45 to 54 years; and 72 per 100 000 for those aged 55 to 64 years. The rates were much lower for men, at 16 per 100 000 for those aged 25 to 34 years; 24 per 100 000 for those aged 35 to 44 years; 26 per 100 000 for those aged 45 to 54 years; and 20 per 100 000 for those aged 55 to 64 years. There were 440 deaths (2.6%), including 159 (36.1%) among male patients and 281 (63.9%) among female patients. The percentage of men dying (5.4%) was almost 3 times that of the women (2.0%). The percentages of black men (6.1%) and black women dying (2.6%) were higher than those of white men (5.0%) and white women (1.9%) (Table 2). The 16 683 bariatric surgical procedures were performed in 74 hospitals. However, 90.3% (n = 15 064) were performed in 32 hospitals and 48.2% (n = 8047) were performed in only 8 hospitals. Three hundred sixty-four of the 440 deaths (82.7%) occurred in the 32 hospitals that contributed more than 90% of the procedures. As noted, only the first surgical procedure has been included in our analyses.

The 30-day case fatality percentage was 0.9% (95% CI, 0.76%-1.05%), excluding 5 traumatic deaths. The 30-day case fatality rate increased with age, especially among those older than 65 years (Table 3). There was little evidence of change in the 30-day case fatality rate over time. Of the 440 deaths, 155 (35.2%) occurred within 1 month; 37 (8.4%), within 1 to 3 months; 34 (7.7%), within 3 to 6 months; 38 (8.6%), within 6 to 12 months; and 176 (40.0%), more than 1 year after bariatric surgery. In all, 164 of 440 cases (37.3%) underwent autopsy, and 125 cases (28.4%) were certified by a coroner or medical examiner. Eighty-eight of the 125 coroner-certified deaths (70.4%) and 76 of the 315 non–coroner-certified deaths (24.1%) underwent autopsy. All of the traumatic deaths, including 16 due to suicide; 10, to motor vehicle crashes; 14, to drug overdoses; 3, to homicides; and 2, to falls, were certified by the coroner, as well as 77 of the 395 nontraumatic deaths (19.5%). The probability of autopsy was inversely related to the time between bariatric surgery and death, including 76 of the 155 deaths in the first 30 days (49.0%) but only 71 of the 285 deaths more than 1 year after the surgical procedure (24.9%).

The cumulative case fatality rate for patients who underwent bariatric surgery and who were at risk for up to 5 years of follow-up, excluding 2004 hospitalizations, was 2.1% (95% CI, 1.8%-2.4%) for less than 1 year; 2.9% (95% CI, 2.5%-3.2%) for 1 to less than 2 years; 3.7% (95% CI, 3.2%-4.3%) for 2 to less than 3 years; 4.8% (95% CI, 4.0%-5.7%) for 3 to less than 4 years; and 6.4% (95% CI, 5.3%-7.8%) for 4 to less than 5 years (Table 4). The time-specific death rates for each year separately were 21.0 per 1000 person-years for less than 1 year, 14.3 per 1000 per-
The age-specific death rates for men and women based on person-years of follow-up from the time of surgery were substantially higher than comparable rates for the age- and sex-matched Pennsylvania population, even after excluding deaths in the first 30 days (Table 5). The age- and sex-specific death rates after bariatric surgery were 16.7 per 1000 person-years for 4 to 5 years of follow-up (data not shown), 13.1 per 1000 person-years for 3 to 4 years of follow-up, and 13.1 per 1000 person-years for 2 to 3 years of follow-up, 12.4 per 1000 person-years for 1 to 2 years of follow-up, and 11.4 per 1000 person-years for 0 to 1 year of follow-up (data not shown).

The age-specific death rates for men and women based on person-years of follow-up from the time of surgery were substantially higher than in men than in women and increased with age (Table 5). The age- and sex-specific death rates after bariatric surgery were substantially higher than comparable rates for the age- and sex-matched Pennsylvania population, even after excluding deaths in the first 30 days (Table 5).

We also estimated the long-term mortality for individuals who had undergone surgery many years ago. For the 1995 cohort who had at least 9 years of follow-up, 13.0% had died. From the 1996 cohort with 8 years of follow-up, 15.8% had died, and from the 1997 cohort with 7 years of follow-up, 10.5% had died. For the 1998-1999 cohorts with 5 to 6 years of follow-up, the total mortality was 7.0% to 2004.

The distribution of causes of death within the first 30 days and during the entire follow-up is shown in Table 6. Therapeutic complications accounted for 38 of the 150 nontraumatic deaths (25.3%) that occurred within the first 30 days, pulmonary embolism for 20.7%, coronary heart disease (CHD) for 17.3%, and sepsis for 11.3% accounting for 74.7% of all deaths within the first 30 days (Table 6). Sepsis (n=19), pulmonary embolism (n=9), and cardiac events (n=5) were the leading causes of death among the total 45 deaths due to therapeutic complications. Other causes of therapeutic complications included respiratory failure and aspiration (n=5), gastrointestinal tract perforation, infarction, or hemorrhage (n=4), and multisystem failure (n=3).

Coronary heart disease was the leading cause among the 395 deaths, at 76 (19.2%) (Table 6). Sepsis (13.9%), pulmonary embolism (11.9%), therapeutic complications (11.4%), cancer (10.6%), and CHD accounted for 67.1% of all natural deaths.

The CHD death rate was much higher for men (78.1 per 10 000, with 37 deaths in 4736 person-years of observation) than for women (14.7 per 10 000, with 33 deaths in 22 406 person-years of observation). The CHD death rates were substantially higher than for similar age groups in Pennsylvania. For example, in the group aged 45 to 54 years, the CHD mortality rate for women after bariatric surgery was 15.2 per 10 000 person-years compared with the rate of similarly aged women in Pennsylvania of 5.46 per 10 000.

The 45 deaths from traumatic causes included 16 deaths (4%) due to suicide and 14 due to drug overdoses (3%) that were not classified as suicide. Twenty-one of these 30 traumatic deaths (70%) occurred more than 1 year after the bariatric surgery and only 2 occurred within the first 30 days. Ten of the 16 deaths due to suicide (62%) and 12 of the 14 due to drug overdoses (86%) were among women. Of the 11 deaths in participants younger than 24 years, 4 (36%) were due to suicide or drug overdose, as were 3 of 37 deaths (8%) in the group aged 25 to 34 years. There were also 10 deaths due to motor vehicle crashes, 3 to homicide, and 2 to falls.

### Table 5. Age, Sex-Specific Death Rates per 1000 Person-Years After Bariatric Surgery in Patients Residing in Pennsylvania

<table>
<thead>
<tr>
<th>Age, y</th>
<th>No. of Study Deaths</th>
<th>Death Rateb</th>
<th>Pennsylvania Death Rate for 2002</th>
<th>Ratio</th>
<th>Ratio c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-34</td>
<td>23</td>
<td>5.0 (3.18-7.50)</td>
<td>0.6</td>
<td>8.3</td>
<td>6.2</td>
</tr>
<tr>
<td>35-44</td>
<td>74</td>
<td>8.3 (6.46-10.40)</td>
<td>1.3</td>
<td>6.4</td>
<td>4.4</td>
</tr>
<tr>
<td>45-54</td>
<td>98</td>
<td>13.1 (10.5-16.2)</td>
<td>2.8</td>
<td>4.7</td>
<td>3.5</td>
</tr>
<tr>
<td>55-64</td>
<td>67</td>
<td>24.8 (19.1-31.9)</td>
<td>7.5</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-34</td>
<td>14</td>
<td>13.8 (7.3-23.6)</td>
<td>1.3</td>
<td>10.6</td>
<td>4.9</td>
</tr>
<tr>
<td>35-44</td>
<td>34</td>
<td>17.4 (11.8-24.6)</td>
<td>2.5</td>
<td>7.0</td>
<td>3.1</td>
</tr>
<tr>
<td>45-54</td>
<td>61</td>
<td>40.9 (31.2-52.8)</td>
<td>4.7</td>
<td>8.7</td>
<td>5.5</td>
</tr>
<tr>
<td>55-64</td>
<td>36</td>
<td>61.7 (43.1-85.9)</td>
<td>11.0</td>
<td>5.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

a Compared with age- and sex-specific death rates per 1000 person-years in all residents of Pennsylvania.
b Indicates rate per 1000 patients undergoing bariatric surgery.
c Excludes deaths in the first 30 days.

### Table 6. Nonviolent Causes of 150 Deaths in the First 30 Days After Surgery and in 395 Total Natural Deaths

<table>
<thead>
<tr>
<th>Cause</th>
<th>In First 30 Days</th>
<th>Total Natural Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapeutic complications</td>
<td>38 (25.3)</td>
<td>45 (11.4)</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>31 (20.7)</td>
<td>47 (11.9)</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>26 (17.3)</td>
<td>76 (19.2)</td>
</tr>
<tr>
<td>Sepsis</td>
<td>17 (11.3)</td>
<td>55 (13.9)</td>
</tr>
<tr>
<td>Lung disease</td>
<td>7 (4.7)</td>
<td>18 (4.6)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>5 (3.3)</td>
<td>16 (4.1)</td>
</tr>
<tr>
<td>Cancer</td>
<td>4 (2.7)</td>
<td>42 (10.6)</td>
</tr>
<tr>
<td>Other heart</td>
<td>3 (2.0)</td>
<td>18 (4.6)</td>
</tr>
<tr>
<td>Liver disease</td>
<td>2 (1.3)</td>
<td>9 (2.3)</td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (1.3)</td>
<td>12 (3.0)</td>
</tr>
<tr>
<td>Multisystem failure</td>
<td>2 (1.3)</td>
<td>4 (1.0)</td>
</tr>
<tr>
<td>ESRD</td>
<td>2 (1.3)</td>
<td>12 (3.0)</td>
</tr>
<tr>
<td>GI tract bleeding event</td>
<td>1 (0.7)</td>
<td>4 (1.0)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1 (0.7)</td>
<td>6 (1.5)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>0</td>
<td>4 (1.0)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (6.0)</td>
<td>27 (6.8)</td>
</tr>
<tr>
<td>Total</td>
<td>150 (100.0)</td>
<td>395 (100.0)</td>
</tr>
</tbody>
</table>

Abbreviations: ESRD, end-stage renal disease; GI, gastrointestinal.
a Excludes 45 traumatic deaths.
The US Vital Statistics rates of death due to suicide for white women are approximately 7 per 100,000 and for white men are 25 per 100,000 among the population aged 25 to 64 years. There were 2245 person-years of observation for women and an estimated 2 suicide deaths should have occurred; for 4736 person-years for men, 1 suicide. There is a substantial excess of suicide deaths, even excluding those listed only as drug overdose.

**COMMENT**

Patients undergoing bariatric surgery had a 1-year case fatality rate of approximately 1% and a 5-year case fatality rate of nearly 6%. Less than 1% of bariatric surgery patients died within the first 30 days after the procedure. The death rates after bariatric surgery remained higher than those for age- and sex-matched Pennsylvania residents. This continued high mortality rate is likely a function of the initial comorbidities related to substantial obesity and the likelihood that the patients remain obese even after the substantial weight loss and have remaining comorbidities.

Flum et al recently reported the follow-up of a Medicare bariatric surgery sample. The 30-day case fatality rate was higher than that for our Pennsylvania sample. For the group aged 25 to 34 years, the Pennsylvania 30-day case fatality rate was 0.4% and the Medicare case fatality rate was 1.1%. Similarly, for the group aged 35 to 44 years, Flum et al reported a 30-day case fatality rate of 1.5% vs the Pennsylvania rate of 0.82%; for the group aged 45 to 54 years, 1.9% vs 1.0% in Pennsylvania; and for the group aged 55 to 64 years, 2.0% vs 1.5% in Pennsylvania.

The only previous population-based study has been recently reported by Flum and Dellinger from the state of Washington. They used the Washington State Hospital database and state vital statistics. The 30-day case fatality rate was 1.9%. Flum and Dellinger compared the survival of the patients who had undergone bariatric surgery with that of other hospitalized obese patients and noted a small decrease in mortality among those who had undergone bariatric surgery compared with obese controls, i.e., 16.3% mortality for obese controls compared with 11.8% of the patients who had undergone bariatric surgery. The obese nonsurgical sample, however, was substantially biased by selection for hospitalization, the Berksonian bias as previously described. Their 30-day case fatality rate was 1.9% compared with 0.9% in the Pennsylvania study. They also reported a 10-year survival of 91.2% based on 233 bariatric surgery cases with 10-year follow-up. The Pennsylvania follow-up from 1997 to 2004 (approximately 8 years) was about 90%, based on 571 bariatric surgery cases performed during that time and 63 subsequent deaths. They did not provide information on causes of death.

The death certificates were carefully reviewed by 2 individuals with expertise in determining of causes of death in other studies (D.G.I. and L.H.K.). However, only 37.3% of the deaths had a postmortem examination. We strongly suspect that some of the CHD deaths were primarily due to obesity-related cardiomyopathies and cardiac arrhythmias. Approximately one-third (24 of the 76 CHD deaths) were certified by the coroner, but only 18 of the 76 CHD deaths (24%) underwent a postmortem examination.

Deaths attributed to other heart disease (10 of 18 [56%]) were certified by the coroner, and 9 of the 10 coroner-certified cases had a postmortem examination. A more thorough examination of cardiac morbidity and mortality, including more detailed clinical evaluations of cardiac pathophysiologic characteristics before and after surgery, is indicated because of the continuing high mortality rate due to cardiovascular disease in this population.

It is very likely that suicide deaths were also underestimated because some of the deaths were listed as drug overdoses rather than suicide on the death certificate. The large number of deaths due to suicide and drug overdose, in excess of what we expected, is also a cause for concern. Most of them occurred at least 1 year after surgery, suggesting that careful follow-up, especially the need to recognize and treat depression, should be provided for patients who have undergone bariatric surgery. Only about 27% of the deaths due to therapeutic accidents were certified by the coroner. Less than two-thirds (28 of 44) underwent autopsy. All deaths that occurred immediately after bariatric surgery were probably reviewed by a coroner or medical examiner and include a postmortem examination, to evaluate the circumstances and specific cause of death. Such information would be useful in enhancing efforts to minimize the 30-day case fatality rate.

Patients who undergo bariatric surgery patients continue to have higher mortality in part because of the obesity and comorbidities before the surgery and probably because of continued obesity or weight regain after the surgery. Our study cannot determine whether surgery reduced mortality compared with patients with class III obesity who did not undergo surgery.

The benefits of bariatric surgery in reducing the prevalence of diabetes, hypertension, high lipid levels, sleep apnea, and other complications of obesity should result in decreased long-term mortality. A recent meta-analysis of surgical treatment for obesity concluded that surgery is more effective than nonsurgical therapy for weight loss and for reducing some comorbid conditions in patients with a body mass index greater than 40. That meta-analysis noted, however, that only a few clinical trials were available for analysis and that these were mostly small studies comparing weight loss over a short period in relationship to different types of surgical procedures. A few studies also included measurements of diabetes mellitus, hypertension, or changes in lipid levels.

The Swedish Obesity Study of bariatric surgery has not reported long-term mortality differences between the surgical group and a nonsurgical control group matched for obesity. An ongoing trial in Utah is comparing 415 patients who underwent bariatric surgery, 420 who sought but were denied bariatric surgery, and a control group of 324 patients with severe obesity. A 24-month evaluation of morbidity was proposed. However, the sample size is too small for the evaluation of major changes in morbidity and mortality among the 3 groups.

It is likely that this continued excess mortality after bariatric surgery could be reduced by better coordination of follow-up after the surgery, especially control of high risk factors such as hypertension, diabetes mellitus, hyperlipidemia, and smoking, as well as efforts to
prevent weight regain by diet and exercise and psychological support to prevent and treat depression and suicide.\textsuperscript{38-40} It is recommended that surgical procedures be performed in institutions that have adequate follow-up of patients and the best practices in bariatric surgery.\textsuperscript{39}

It is unlikely, for now, that a true randomized trial of bariatric surgery vs nonsurgical treatment will be performed. As changes in the types of bariatric surgery become available, as well as new potent pharmacological therapies to reduce weight, large randomized trials with morbidity and mortality outcomes could compare different types of surgical procedures or surgical therapy vs potent pharmacological therapies and morbidity and mortality outcomes.

In the meantime, objective independent monitoring of the outcomes of bariatric surgery, such as in the Pennsylvania study, and especially more careful evaluation of specific causes of death and circumstances related to the deaths could lead to better identification of preventable morbidity and mortality and to improved outcomes for the patients.

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