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Thyroidectomy as Primary Treatment Optimizes BMI in Patients with Hyperthyroidism

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Abstract

Objective—The purpose of this study was to determine how the timing of thyroidectomy influenced postoperative weight change.

Methods—We conducted a two institution study, identifying patients treated with total thyroidectomy for hyperthyroidism. Patients were classified as “early” if they were referred for surgery as the first treatment option or “delayed” if they were previously treated with radioactive iodine. Groups were compared with the student's t-test or Chi-squared test where appropriate.

Results—There were 204 patients undergoing thyroidectomy for hyperthyroidism. 171 patients were classified as early and 33 were delayed. Overall, patients gained $6.0\% \pm 0.8$ of their preoperative body weight at last follow-up. Preoperative BMIs were similar between groups ($p = 0.98$), and the median follow-up time was 388 days (range 15 – 1,584 days). Both groups gained weight until they achieved a normal TSH postoperatively. After achieving a normal TSH, the early group stabilized or lost weight (-0.2 lbs/day) while the delayed group continued to gain weight (0.02 lbs/day, $p = 0.61$). At last follow-up, there were significantly more patients in the delayed group who increased their BMI category compared to the early group (42.4% vs. 21.6% , $p = 0.01$). Twice as many patients in the delayed group moved up or into an unhealthy BMI category (overweight or obese) compared to the early group (39.4% vs. 19.3% , $p = 0.01$).

Conclusions—Compared to patients initially treated with radioactive iodine, patients with hyperthyroidism who underwent surgery as the first treatment were less likely to become overweight or obese postoperatively.

Introduction

Hyperthyroidism is caused by autoimmune thyroid disease or autonomously functioning thyroid tissue. Graves' disease is an autoimmune thyroiditis and the most common type of hyperthyroidism. A toxic solitary nodule or toxic multinodular goiter results from diffuse or localized hyperplasia of thyroid follicular cells that continue to produce excessive thyroid

hormone independent of TSH. Regardless of the underlying etiology, hyperthyroidism affects almost every organ system in the body with sweating, tachycardia, hypertension, hyperdefecation, bone resorption, tremor, agitation, and insomnia (1). Weight loss occurs through several mechanisms, with the primary cause being an increased metabolic rate. An increased basal metabolic rate increases energy expenditure and, therefore, weight loss ensues (2-4). Secondary causes of weight loss include the increased bowel motility and malabsorption associated with the hyperdefecation.

The first step in treating hyperthyroidism is to render the patient euthyroid through anti-thyroid medications. Once the patient is euthyroid, there are three definitive treatment options: 1) continued use of antithyroid medications, 2) radioactive iodine (RAI), or 3) thyroidectomy. Due to adverse effects of long-term antithyroid medications, most patients must choose between RAI and surgery as the definitive treatment strategy (1). Historically, the majority of patients initially received RAI. Reported recurrence rates after RAI treatment range from 10 to 40 percent of patients (5-7). Patients who recur can either elect treatment with a second dose of RAI or undergo thyroidectomy.

The American Thyroid Association (ATA) and the American Association of Clinical Endocrinologists (AACE) published revised guidelines for the treatment of hyperthyroidism in 2011 (8). Whereas previous versions of these guidelines favored radioactive iodine over surgery, these most recent guidelines considered thyroidectomy as an equal treatment option to radioactive iodine (8, 9). This change in guidelines was prompted in part by the demonstration of safety and efficacy for total thyroidectomy when performed by a high volume surgeon (10-12).

In this context, patients and their physicians must decide whether surgery or radioactive iodine is the best initial treatment option. Patients making this decision often have questions about how treatment of hyperthyroidism will affect their weight. The weight gain observed after treatment of hyperthyroidism has been conventionally viewed as a return to the patient's pre-morbid weight (13). This expected, or appropriate, weight gain results from increased food energy intake that plateaus as weight rises (14). Long-term studies have supported this general rule. In one study, after treatment of hyperthyroidism, patients sustained a mean increase in BMI of 2.3 kg/m² above their pre-treatment weight through 5 years post-therapy. After this initial increase, BMI no longer increased over the remainder of the 10-year follow-up period (15). Increased lean body mass accounts for the majority of this initial weight gain (3, 4, 15, 16).

While these studies primarily included patients treated with either RAI and anti-thyroid medications, Dale and colleagues found that patients treated with thyroidectomy gained more weight compared to patients treated with either RAI or anti-thyroid medications (17). Jonklaas and Nsouli-Maktabi found that even euthyroid patients gained weight after thyroidectomy, raising the question of whether something about thyroidectomy itself contributes to weight gain (18).

Yet, patients often receive more than one treatment modality for hyperthyroidism, especially if it recurs. For example, many patients with hyperthyroidism first receive one or more doses

of RAI before surgical referral (1, 10). The purpose of this study was to examine patterns of weight change after thyroidectomy for hyperthyroidism. Specifically, we compared two broad categories of patients treated with thyroidectomy for hyperthyroidism—patients receiving thyroidectomy as their first, or early, treatment modality versus patients who first receive RAI and then undergo a later, or delayed, thyroidectomy.

Methods

We conducted a two institution retrospective review of prospectively maintained thyroid databases from two high-volume centers, selecting patients undergoing total thyroidectomy for Graves' disease or toxic multinodular goiter between 7/1/2007 and 12/31/2012. We selected patients with preoperative and postoperative body weight data available. Only patients with weight data at the time of their first postoperative normal TSH and at least one subsequent time point were selected for further analysis (204 of 269 total patients). Patients who were pregnant (two patients) or had other non-thyroid conditions or treatments likely to contribute to weight gain were excluded (one patient treated with high dose steroids for a rheumatologic condition). Patients were classified as either “early” if they were referred for surgery as the first definitive treatment option or “delayed” if they were previously treated with radioactive iodine or an extended period (≥ 6 months) of anti-thyroid medications.

Patient weights at three time points were recorded (preoperative, first postoperative normal TSH, and last follow-up), and body mass index (BMI) calculated. At each time point, patient BMIs were classified as follows: underweight (<18.5 kg/m²), normal ($18.5 - 24.9$ kg/m²), overweight ($25 - 29.9$ kg/m²), or obese (≥ 30 kg/m²) (19, 20). Weight change was considered unhealthy if a subject moved into either the overweight or obese BMI categories and healthy if a patient moved from the underweight to the normal category.

Regression was used to fit the optimal curves to the patterns of weight change. Linear regression was used to calculate rates of weight change. Comparisons between groups were made using the student's t-test, Chi-squared test, or Wilcoxon Rank-sum test where appropriate. $P < 0.05$ was considered significant. All statistics were computed using STATA version 12.1 (Stata Corp, College Station, TX). This study was approved by the Institutional Review Boards (IRBs) from the University of Wisconsin and Vanderbilt University Medical Center.

Results

Pre-operative characteristics

There were a total of 204 patients from two institutions undergoing total thyroidectomy for hyperthyroidism. 171 patients (83.8%) were classified as early and 33 (16.2%) were delayed. The early and delayed groups did not differ in terms of their age or gender distributions, nor did they have different frequencies of coronary artery disease, diabetes, or congestive heart failure (Table 1). Disease features such as the proportion of patients with ophthalmopathy or the percentage uptake on thyroid uptake scans also did not differ between the groups (Table 1). Preoperative thyroid function (TSH and free T4) were equivalent between the early and delayed groups (Table 1). Importantly, baseline weight and BMI were

similar when comparing the early to the delayed groups as shown in Table 1. Furthermore, the distribution of patients who were underweight, normal, overweight, or obese preoperatively was also similar between the two groups (Table 1).

The etiology of hyperthyroidism was Graves' disease in 135 patients (66.2%), and the remaining 69 patients (33.8%) had a toxic multinodular goiter (Table 1). In comparing the Graves' patients to those with toxic multinodular goiter, there were no differences in age, gender, or co-morbidities. However, all the underweight patients had Graves' disease, and therefore this group had a lower preoperative BMI ($p = 0.03$). However, there was no difference in the proportion of patients with Graves' disease in the early and delayed groups (66.7% early vs. 60.6% late, $p = 0.43$, Table 1).

Patients in the early group were referred for surgery a median of 1.5 months (range 0.5 months – 4.7 months) after diagnosis whereas those in the delayed group were referred at a median of 10.3 months after diagnosis (range 6.0 – 22.6 months). Within the delayed group, 22 patients (66.7%) received RAI.

Patterns of weight change after thyroidectomy

Overall, patients gained $6.0\% \pm 0.8$ of their preoperative body weight by last follow-up. The median follow-up time was 388 days (range 15 – 1,584 days).

The time after thyroidectomy was divided into two periods: 1) the time between surgery and their first normal TSH, and 2) the period between normalization of TSH and last follow-up weight. Linear regression was used to calculate rates of weight change in these two periods. Both groups gained weight during the initial period between surgery and the first normal TSH, but rates of weight change were not statistically different between the early and delayed groups (0.01 ± 0.08 lbs/day, early vs. 0.06 ± 0.03 lbs/day, delayed, $p = 0.82$). After achieving a normal TSH, the early group stabilized or lost weight (-0.2 lbs/day) while the delayed group continued to gain weight (0.02 lbs/day, $p = 0.61$).

Although there was no statistical difference in the slopes, we also fit the optimal quadratic curve to the overall pattern of weight change for both groups (Figure 1). The early group displays an exponential increase in weight until normalization of their TSH. After normalization of their TSH, weight gain in the early group stabilized, whereas the delayed group continued to gain weight in a linear fashion. Consistent with this pattern, significantly more patients in the early group stabilized (no change) or lost weight after normalization of their TSH when compared to the delayed group (66.1% vs. 42.4%, $p = 0.01$).

Change in BMI classification

While both groups did gain weight, a small portion of the weight gain in the early group was healthy. The early group experienced a significant decrease in the percentage of underweight patients between surgery and their first normal TSH (4.4% to 2.0%, $p = 0.01$). There were no patients in the delayed group who were underweight preoperatively.

When comparing the portion of patients who changed their BMI classification, more patients in the delayed group gained enough weight to move up in their BMI classification. By the

time patients normalized their TSH postoperatively, 30.3% in the delayed group increased their BMI classification while only 18.7% in the early group moved up in BMI category ($p = 0.13$, Figure 2A). At last follow-up, there were significantly more patients in the delayed group who increased their BMI category compared to the early group (Figure 2A, 42.4% vs. 21.6%, $p = 0.01$). If movement into the overweight or obese BMI categories is considered unhealthy, then more patients in the delayed group experienced an unhealthy change in BMI. At the time of their first normal TSH after surgery, 17.0% of patients in the early group and 27.3% of patients in the delayed group had an unhealthy change in BMI category ($p = 0.16$, Figure 2B). By the last follow-up, twice as many patients in the delayed group moved up or into an unhealthy BMI category (overweight or obese) compared to the early group (39.4% vs. 19.3%, $p = 0.01$, Figure 2B).

We also compared weight change in those with Graves' disease to those with toxic multinodular goiter. Although there were no differences between these two groups in terms of the portion of patients experiencing an unhealthy weight gain (overweight/obese), those with toxic multinodular goiter were more likely to increase their BMI classification compared to those with Graves' disease (32.8% vs. 12.23%, $p = 0.04$).

Complications

The early group experienced significantly more temporary hypocalcemia compared to the delayed group (25.3% vs. 9.1%, $p = 0.02$, Table 2). Importantly, there were no differences in the rate of permanent complications between the two groups (Table 2).

Discussion

Weight change related to any treatment for thyroid disorders remains a controversial topic. Much attention has focused on the relationship between thyroid function and weight change for several reasons: 1) the obesity epidemic in the United States, 2) popular media interest to thyroid function and body weight, and 3) scientific focus on the relationship between weight and hormones like leptin and T3 (21-25). For these reasons, patients presenting for thyroidectomy as a definitive treatment of hyperthyroidism have many questions about weight gain after surgery.

In this study, we found that, compared to patients initially treated with surgery, those first treated with a trial of anti-thyroid medications or RAI had more unhealthy weight change after thyroidectomy. While both groups initially gained weight until normalization of their TSH, patients treated promptly with surgery began to stabilize or lose weight after their TSH normalized while patients undergoing delayed surgery continued to gain weight (Figure 1). By last follow-up, more patients in the delayed group experienced an unhealthy weight change as compared to the group initially treated with surgery (Figure 2). Although two-thirds of patients in the delayed group were initially treated with RAI, use of RAI was not ubiquitous among the delayed group. In this surgical series, the common feature within the delayed group was the timing of surgery at least 6 months after diagnosis, with a median of more than 10 months between diagnosis and surgery. These results imply that the timing of surgical treatment for hyperthyroidism may influence patterns of weight gain postoperatively.

Weight gain clearly has an impact on overall health and is linked to increased morbidity and mortality due to its effects on almost every organ system in addition to its social and economic impact (19, 26-28). In the era of an obesity epidemic, physicians and patients consider the potential for weight gain in all medical domains, including endocrinology and surgery. Here, we demonstrate that patients referred for surgery after failed RAI or antithyroid medications had a higher likelihood of moving to an unhealthy BMI category. Currently, weight gain is not considered when deciding the original course of treatment for hyperthyroidism, but these results suggest that weight might become part of this discussion, especially for patients who are already overweight or obese.

Although it is well established that hyperthyroidism causes weight loss and treatment that successfully normalizes thyroid function leads to weight regain, there is no consensus on whether the weight gain exceeds pre-morbid weight (2, 14, 17, 29). Excessive, or unhealthy weight gain has been documented in a few studies (17, 30), but others suggest weight gain is appropriate since it represents restoration of lean body tissues such as bone and skeletal muscle rather than fat (2, 13, 29).

Patients undergoing thyroidectomy as definitive treatment for hyperthyroidism are underrepresented in these studies. Dale and colleagues compared patterns of weight gain between those treated with anti-thyroid medications, RAI, and surgery for hyperthyroidism. They found that surgery patients gained more weight (approximately 10 Kg) compared to patients treated with the other two modalities (17). This study only included 13 patients treated with thyroidectomy. The authors indicate that "surgery...was reserved for patients with contraindications to both thionamides and radioiodine, obstructive symptoms from goiters or patient preference" (17). Under these conditions, many of these patients would have been classified as "delayed" in the study presented here.

There are several potential explanations why more patients in the delayed group experienced unhealthy weight change than the early group. Although the early group did start out with more underweight patients preoperatively, this number was fairly small (8 patients, 4.7%, Table 1). As expected, the underweight patients all had Graves' disease, but there was no difference in the portion of Graves' patients in the early and delayed groups. Furthermore, there were no preoperative differences in the distribution of BMIs. Nonetheless, the chronicity or duration of disease was likely much different between the groups, with patients initially treated with RAI spending longer periods of time on anti-thyroid medications. In this group, the indication for surgery was recurrence or failure of RAI and/or anti-thyroid medications.

As patients spend more time on anti-thyroid medications, they are more likely to develop hypothyroidism. Dale and colleagues found that patients who developed hypothyroidism, even transiently, had larger amounts of weight gain (17). Several population-based studies have demonstrated a correlation between serum TSH and weight gain, even for modest TSH elevations within the normal range (21, 31, 32). Unfortunately, we cannot report the kinetics TSH change preoperatively in this study, and it is possible that the delayed group experienced more elevations in TSH due to titration of anti-thyroid medications or transient effects of RAI.

Aside from cycling of TSH, there are several other theoretical explanations for weight gain after treatment of hyperthyroidism. These include mismatch between appetite, physical activity, and changes in metabolic rate that occur with changes in thyroid hormone levels (2, 14, 17, 33). In addition, thyroid hormone levels are linked to appetite and body fat regulatory hormones like ghrelin and leptin. Subclinical hyper- or hypothyroidism may lead to dysregulation of these hormones and contribute to weight gain (2, 13-15, 17, 22, 33-41).

Any potential benefit from weight change must be weighed against the potential risks of early thyroidectomy. Although the early group experienced more temporary hypocalcemia, there were no differences in the rate of permanent complications. Arguments against thyroidectomy for hyperthyroidism include a prohibitively high complication rate (42-45), but in this series of patients treated at two high volume centers, we demonstrate no differences in the rate of permanent complications, suggesting that early surgical intervention for hyperthyroidism is not necessarily more dangerous than waiting for these patients to fail other modalities. This is consistent with other published series from high volume centers (10, 42, 43, 46)

This study is limited by its retrospective nature. Since this is a surgical series, we do not have detailed information regarding preoperative weight change and duration of hyper- or hypothyroidism prior to surgery. These factors likely contribute to postoperative patterns of weight change as discussed above. Furthermore, the rationale for initially treating patients with either surgery or RAI was not always obvious from retrospective chart review. Since this is a surgical series, there are many more patients in the early group, and the delayed group may represent a subset of all patients initially treated with RAI. Future research will also include a control group treated with RAI alone. Practice patterns have changed since the revision of ATA guidelines in 2011 (8), and therefore, selection bias likely exists as patients with more severe disease were likely offered thyroidectomy as the initial treatment. Non-thyroid co-morbidities felt to make surgery as the initial therapy more dangerous might also lead to increased weight gain postoperatively. We have tried to control for this by comparing co-morbidities that might pre-dispose to weight gain (coronary disease, heart failure, and diabetes). Finally, although our median follow-up time exceeded one year, longer follow-up time might have revealed that the delayed group eventually stabilizes their weight, but the plateau takes longer to occur. This is an equally unhealthy pattern since the tendency is to gain and not lose weight with age.

Despite these weaknesses, this study is one of the largest to date of hyperthyroid patients treated with thyroidectomy. Patients operated on in a delayed fashion were more likely to experience unhealthy weight gain postoperatively compared to those initially treated with surgery. Further investigation into the mechanisms behind weight gain after different treatments for hyperthyroidism is clearly needed to identify patients at risk for unhealthy weight gain. In light of the data presented here and elsewhere showing the safety of surgery for hyperthyroidism, patients who are already overweight or at the upper limits of the normal BMI should consider surgery as their initial treatment modality to limit detrimental weight gain postoperatively.

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References

1. Schussler-Fiorenza CM, Bruns CM, Chen H. The surgical management of Graves' disease. *J Surg Res.* 2006; 133(2):207–14. [PubMed: 16458922]
2. Jacobsen R, Lundsgaard C, Lorenzen J, Toubro S, Perrild H, Krog-Mikkelsen I, et al. Subnormal energy expenditure: a putative causal factor in the weight gain induced by treatment of hyperthyroidism. *Diabetes Obes Metab.* 2006; 8(2):220–7. [PubMed: 16448527]
3. Astrup A, Buemann B, Christensen NJ, Madsen J, Gluud C, Bennett P, et al. The contribution of body composition, substrates, and hormones to the variability in energy expenditure and substrate utilization in premenopausal women. *J Clin Endocrinol Metab.* 1992; 74(2):279–86. [PubMed: 1530952]
4. Toubro S, Sorensen TI, Ronn B, Christensen NJ, Astrup A. Twenty-four-hour energy expenditure: the role of body composition, thyroid status, sympathetic activity, and family membership. *J Clin Endocrinol Metab.* 1996; 81(7):2670–4. [PubMed: 8675595]
5. Topping O, Tallstedt L, Wallin G, Lundell G, Ljunggren JG, Taube A, et al. Graves' hyperthyroidism: treatment with antithyroid drugs, surgery, or radioiodine--a prospective, randomized study. *Thyroid Study Group. J Clin Endocrinol Metab.* 1996; 81(8):2986–93. [PubMed: 8768863]
6. Porterfield JR Jr, Thompson GB, Farley DR, Grant CS, Richards ML. Evidence-based management of toxic multinodular goiter (Plummer's Disease). *World J Surg.* 2008; 32(7):1278–84. [PubMed: 18357484]
7. Hegedus L. Treatment of Graves' hyperthyroidism: evidence-based and emerging modalities. *Endocrinol Metab Clin North Am.* 2009; 38(2):355–71, ix. [PubMed: 19328416]
8. Bahn Chair RS, Burch HB, Cooper DS, Garber JR, Greenlee MC, Klein I, et al. Hyperthyroidism and other causes of thyrotoxicosis: management guidelines of the American Thyroid Association and American Association of Clinical Endocrinologists. *Thyroid.* 2011; 21(6):593–646. [PubMed: 21510801]
9. Baskin HJ, Cobin RH, Duick DS, Gharib H, Guttler RB, Kaplan MM, et al. American Association of Clinical Endocrinologists medical guidelines for clinical practice for the evaluation and treatment of hyperthyroidism and hypothyroidism. *Endocr Pract.* 2002; 8(6):457–69. [PubMed: 15260011]
10. Liu J, Bargren A, Schaefer S, Chen H, Sippel RS. Total thyroidectomy: a safe and effective treatment for Graves' disease. *The Journal of surgical research.* 2011; 168(1):1–4. [PubMed: 21345453]
11. Annerbo M, Stalberg P, Hellman P. Management of Grave's disease is improved by total thyroidectomy. *World J Surg.* 2012; 36(8):1943–6. [PubMed: 22547016]
12. Wilhelm SM, McHenry CR. Total thyroidectomy is superior to subtotal thyroidectomy for management of Graves' disease in the United States. *World J Surg.* 2010; 34(6):1261–4. [PubMed: 20033406]
13. Hoogwerf BJ, Nuttall FQ. Long-term weight regulation in treated hyperthyroid and hypothyroid subjects. *Am J Med.* 1984; 76(6):963–70. [PubMed: 6731468]
14. Abid M, Billington CJ, Nuttall FQ. Thyroid function and energy intake during weight gain following treatment of hyperthyroidism. *J Am Coll Nutr.* 1999; 18(2):189–93. [PubMed: 10204837]
15. de la Rosa RE, Hennessey JV, Tucci JR. A longitudinal study of changes in body mass index and total body composition after radioiodine treatment for thyrotoxicosis. *Thyroid.* 1997; 7(3):401–5. [PubMed: 9226210]
16. Greenlund LJ, Nair KS, Brennan MD. Changes in body composition in women following treatment of overt and subclinical hyperthyroidism. *Endocr Pract.* 2008; 14(8):973–8. [PubMed: 19095595]
17. Dale J, Daykin J, Holder R, Sheppard MC, Franklyn JA. Weight gain following treatment of hyperthyroidism. *Clin Endocrinol (Oxf).* 2001; 55(2):233–9. [PubMed: 11531931]

18. Jonklaas J, Nsouli-Maktabi H. Weight changes in euthyroid patients undergoing thyroidectomy. *Thyroid*. 2011; 21(12):1343–51. [PubMed: 22066482]
19. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999–2008. *JAMA*. 2010; 303(3):235–41. [PubMed: 20071471]
20. Tenconi SM, Boni L, Colombo EM, Dionigi G, Rovera F, Cassinotti E. Laparoscopic cholecystectomy as day-surgery procedure: current indications and patients' selection. *Int J Surg*. 2008; 6(Suppl 1):S86–8. [PubMed: 19167938]
21. Kitahara CM, Platz EA, Ladenson PW, Mondul AM, Menke A, Berrington de Gonzalez A. Body fatness and markers of thyroid function among U.S. men and women. *PLoS ONE*. 2012; 7(4):e34979. [PubMed: 22511976]
22. Pearce EN. Thyroid hormone and obesity. *Curr Opin Endocrinol Diabetes Obes*. 2012; 19(5):408–13. [PubMed: 22931855]
23. Zimmermann-Belsing T, Feldt-Rasmussen U. Obesity: the new worldwide epidemic threat to general health and our complete lack of effective treatment. *Endocrinology*. 2004; 145(4):1501–2. [PubMed: 15026374]
24. [cited 2013 April 4] Adult Obesity Facts. Available from: <http://www.cdc.gov/obesity/data/adult.html>
25. Feldt-Rasmussen U. Thyroid and leptin. *Thyroid*. 2007; 17(5):413–9. [PubMed: 17542671]
26. Nguyen DM, El-Serag HB. The epidemiology of obesity. *Gastroenterol Clin North Am*. 2010; 39(1):1–7. [PubMed: 20202574]
27. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med*. 2007; 357(4):370–9. [PubMed: 17652652]
28. Dixon JB. Obesity and diabetes: the impact of bariatric surgery on type-2 diabetes. *World journal of surgery*. 2009; 33(10):2014–21. [PubMed: 19421812]
29. Lonn L, Stenlof K, Ottosson M, Lindroos AK, Nystrom E, Sjostrom L. Body weight and body composition changes after treatment of hyperthyroidism. *J Clin Endocrinol Metab*. 1998; 83(12):4269–73. [PubMed: 9851762]
30. Jansson S, Berg G, Lindstedt G, Michanek A, Nystrom E. Overweight—a common problem among women treated for hyperthyroidism. *Postgrad Med J*. 1993; 69(808):107–11. [PubMed: 8506188]
31. Svare A, Nilsen TI, Bjoro T, Asvold BO, Langhammer A. Serum TSH related to measures of body mass: longitudinal data from the HUNT Study, Norway. *Clin Endocrinol (Oxf)*. 2011; 74(6):769–75. [PubMed: 21521278]
32. Fox CS, Pencina MJ, D'Agostino RB, Murabito JM, Seely EW, Pearce EN, et al. Relations of thyroid function to body weight: cross-sectional and longitudinal observations in a community-based sample. *Arch Intern Med*. 2008; 168(6):587–92. [PubMed: 18362250]
33. Morley JE. Neuropeptide regulation of appetite and weight. *Endocr Rev*. 1987; 8(3):256–87. [PubMed: 3308444]
34. Brennan AM, Mantzoros CS. Drug Insight: the role of leptin in human physiology and pathophysiology—emerging clinical applications. *Nat Clin Pract Endocrinol Metab*. 2006; 2(6):318–27. [PubMed: 16932309]
35. Carleton RA, Lasater TM, Assaf AR, Feldman HA, McKinlay S. The Pawtucket Heart Health Program: community changes in cardiovascular risk factors and projected disease risk. *Am J Public Health*. 1995; 85(6):777–85. [PubMed: 7762709]
36. Dubuc GR, Phinney SD, Stern JS, Havel PJ. Changes of serum leptin and endocrine and metabolic parameters after 7 days of energy restriction in men and women. *Metabolism*. 1998; 47(4):429–34. [PubMed: 9550541]
37. Hsieh CJ, Wang PW, Wang ST, Liu RT, Tung SC, Chien WY, et al. Serum leptin concentrations of patients with sequential thyroid function changes. *Clin Endocrinol (Oxf)*. 2002; 57(1):29–34. [PubMed: 12100066]
38. Inui A, Asakawa A, Bowers CY, Mantovani G, Laviano A, Meguid MM, et al. Ghrelin, appetite, and gastric motility: the emerging role of the stomach as an endocrine organ. *FASEB J*. 2004; 18(3):439–56. [PubMed: 15003990]
39. Kojima M, Hosoda H, Date Y, Nakazato M, Matsuo H, Kangawa K. Ghrelin is a growth-hormone-releasing acylated peptide from stomach. *Nature*. 1999; 402(6762):656–60. [PubMed: 10604470]

40. Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB. Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med*. 2011; 364(25):2392–404. [PubMed: 21696306]
41. Rojdmarm S, Calissendorff J, Danielsson O, Brismar K. Hunger-satiety signals in patients with Graves' thyrotoxicosis before, during, and after long-term pharmacological treatment. *Endocrine*. 2005; 27(1):55–61. [PubMed: 16077172]
42. Hallgrimsson P, Nordenstrom E, Bergenfelz A, Almquist M. Hypocalcaemia after total thyroidectomy for Graves' disease and for benign atoxic multinodular goitre. *Langenbeck's archives of surgery/Deutsche Gesellschaft fur Chirurgie*. 2012; 397(7):1133–7.
43. Welch KC, McHenry CR. Total thyroidectomy: is morbidity higher for Graves' disease than nontoxic goiter? *The Journal of surgical research*. 2011; 170(1):96–9. [PubMed: 21550063]
44. Wong KP, Lang BH. Graves' ophthalmopathy as an indication increased the risk of hypoparathyroidism after bilateral thyroidectomy. *World journal of surgery*. 2011; 35(10):2212–8. [PubMed: 21858556]
45. Solomon B, Glinioer D, Lagasse R, Wartofsky L. Current trends in the management of Graves' disease. *The Journal of clinical endocrinology and metabolism*. 1990; 70(6):1518–24. [PubMed: 1693371]
46. Khadra M, Delbridge L, Reeve TS, Poole AG, Crummer P. Total thyroidectomy: its role in the management of thyroid disease. *The Australian and New Zealand journal of surgery*. 1992; 62(2): 91–5. [PubMed: 1586312]

Abbreviations

BMI	body mass index
TSH	thyroid stimulating hormone
RAI	radioactive iodine
ATA	American Thyroid Association
AACE	American Association of Clinical Endocrinologists
IRB	Institutional Review Board

Figure 1. Kinetics of postoperative weight change

Regression was used to fit the best curve of weight change over time. The early group (solid line) and delayed group (dashed line) are shown. Data are presented as the percentage of pre-operative weight.

Figure 2. Changes in BMI Classification

The proportion of patients who moved up or into an unhealthy (overweight or obese) BMI category (A) and the proportion of patients who increased their BMI (B) are shown for both the early (black) and delayed (gray) groups.

Table 1
Preoperative Features

Variable	Early (n = 171)	Delayed (n = 33)	p value
DEMOGRAPHICS			
Age	43.0 ± 1	42.4 ± 2.5	0.85
Female gender	144 (84.2%)	26 (78.8 %)	0.67
CO-Morbidities			
Diabetes	7 (4.1%)	3 (9.1%)	0.21
CAD	5 (2.9%)	0	1.00
CHF	3 (1.75%)	0	1.00
DISEASE FEATURES			
Graves' disease	114 (66.7%)	20 (60.6%)	0.43
Smoker	51 (29.8%)	14 (42.4%)	0.16
Eye disease	57 (33.3%)	11 (33.3%)	1.00
% Uptake*	57.8 ± 2.9	51.5 ± 4.6	0.28
TSH	0.5 ± 0.2	0.7 ± 0.3	0.30
Free T4	1.7 ± 0.2	1.4 ± 0.2	0.42
WEIGHT & BMI			
Weight (kg)	79.7 ± 1.7	81.5 ± 3.2	0.67
BMI (kg/m ²)	28.7 ± 0.6	28.7 ± 1.1	0.98
BMI Category [#]			0.59
Underweight	8 (4.7%)	0	
Normal	56 (32.8%)	10 (3.3%)	
Overweight	46 (26.9%)	9 (27.3%)	
Obese	61 (35.7%)	14 (42.4%)	

Data are represented as the mean ± standard error of the mean for continuous variables or as the number in each category with the percentage in parentheses for categorical variables.

* Indicates the percentage uptake as measured by a radioiodine uptake scan

[#] Standard BMI category definitions were used: underweight (<18.5 kg/m²), normal (18.5 – 24.9 kg/m²), overweight (25 – 29.9 kg/m²), or obese (≥ 30 kg/m²).

TSH = thyroid stimulating hormone, T4 = thyroxine, CAD = coronary artery disease, CHF = congestive heart failure, BMI = body mass index, Kg = kilograms, m² = meters squared

Table 2

Complications

Type	Early (n = 171)	Delayed (n = 33)	p value
Temporary			
hypocalcemia	43 (25.3%)	3 (9.1%)	0.02
hoarseness	16 (5.3%)	0	0.08
Permanent			
hypocalcemia	5 (3.1%)	1 (3.3%)	1.00
hoarseness	3 (1.7%)	0	1.00
Hematoma	1 (0.6%)	0	1.00
Overall	55 (32.4%)	4 (12.1%)	0.01