Effect of Roux-en-Y gastric bypass on pharmacologic dependence in obese patients with type 2 diabetes

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Background: More than half the diabetes-related health care costs in Canada relate to drug costs. We aimed to determine the effect of Roux-en-Y gastric bypass (RYGB) on the use of insulin and orally administered hypoglycemic medications in patients with diabetes. We also looked to determine overall cost savings with the procedure.

Methods: We reviewed the bariatric clinic records of all patients with a confirmed diagnosis of type 2 diabetes mellitus who underwent RYGB between 2010/11 and 2014/15. Percentage estimated weight loss was recorded at 1 year, along with reductions in glycated hemoglobin (HbA_{1c}) level and use of oral hypoglycemic therapy and insulin. We estimated medication costs using Manitoba-specific pricing data.

Results: Fifty-two patients with at least 12 months of complete follow-up data were identified. The mean percentage estimated weight loss was 50.2%. The mean HbA_{1c} level decreased from 7.6% to 6.0%, the mean number of orally administered hypoglycemics declined from 1.6 to 0.2, and the number of patients receiving insulin decreased from 18 (35%) to 3 (6%) (all $p < 0.001$). The rate of resolution of type 2 diabetes was 71%. Estimated mean annual per-patient medication costs decreased from \$508.56 to \$79.17 ($p < 0.001$). Potential overall health care savings could total \$3769 per patient in the first year, decreasing to \$1734 at 10 years.

Conclusion: Roux-en-Y gastric bypass resulted in significant improvement in diabetic control, with a reduction in hypoglycemic medication use and associated costs in the early postoperative period. Potentially, large indirect and direct cost savings can be realized in the longer term.

Contexte : Plus de la moitié des coûts des soins de santé liés au diabète au Canada sont générés par les médicaments. Nous avons voulu déterminer l'effet de la dérivation gastrique de Roux-en-Y sur l'utilisation des agents hypoglycémiants oraux et de l'insuline chez les patients diabétiques. Nous avons aussi cherché à déterminer l'ensemble des économies associées à cette intervention.

Méthodes : Nous avons passé en revue les dossiers cliniques bariatriques de tous les patients ayant un diagnostic confirmé de diabète de type 2 qui ont subi une dérivation gastrique de Roux-en-Y entre 2010–2011 et 2014–2015. La perte de poids — estimée en pourcentage — a été notée après un an, ainsi que les réductions des taux d'hémoglobine glyquée (HbA_{1c}) et du recours aux hypoglycémiants oraux et à l'insuline. Nous avons estimé les coûts des médicaments à partir des données de tarification du Manitoba.

Résultats : Cinquante-deux patients pour lesquels on disposait d'au moins 12 mois de données de suivi complètes ont été retenus. La perte de poids moyenne estimée en pourcentage était de 50,2 %. Le taux moyen d'HbA_{1c} a diminué de 7,6 % à 6,0 %, le nombre moyen de comprimés d'hypoglycémiants oraux est passé de 1,6 à 0,2, et le nombre de patients sous insuline a diminué de 18 (35 %) à 3 (6 %) (tous $p < 0,001$). Le taux de résolution du diabète de type 2 était de 71 %. Le coût annuel moyen estimé des médicaments par patient est passé de 508,56 \$ à 79,17 \$ ($p < 0,001$). Les économies potentielles globales pour le système de santé pourraient totaliser 3769 \$ par patient au cours de la première année, puis passer graduellement à 1734 \$ au cours des 10 années suivantes.

Conclusion : La dérivation gastrique de Roux-en-Y a permis d'améliorer significativement le contrôle du diabète, ainsi que de réduire le recours aux hypoglycémiants et les coûts associés au début de la période postopératoire. À plus long terme, d'importantes économies sur le plan des coûts indirects et directs pourraient potentiellement être réalisées.

Obesity-related type 2 diabetes mellitus is a growing pandemic. In 2015, just over 3 million Canadians had a diagnosis of type 2 diabetes.[1] The majority of these patients are overweight or obese.[2] Patients with diabetes are much more likely than those without the disease to be admitted to hospital, to require renal replacement therapy and to undergo major amputation.[2] Optimal long-term glycemic control can minimize the incidence of these complications but is difficult to achieve with medical management alone.[3,4]

Bariatric surgery is increasingly indicated in patients with type 2 diabetes and a body mass index (BMI) greater than 35. Several studies have shown that bariatric surgery can achieve dramatic early improvements in glycemic control.[5–9] Although patients may relapse, long-term studies have shown acceptable remission rates.[10–12] In 2 recent long-term randomized trials, a substantial proportion (29%–37%) of patients maintained diabetes remission at 5 years.[13,14] Among patients who did not achieve full remission or who relapsed, diabetic control was better maintained and medication use was lower than in patients who did not have bariatric surgery. In addition, bariatric surgery has been shown to decrease both micro- and macrovascular complications of diabetes in long-term follow-up studies.[8,12,13]

Direct and indirect diabetes-related health care costs in Canada are estimated at $10.1 billion and are predicted to rise to $13.8 billion by 2020.[15] Bariatric surgery is expensive, and patients require multidisciplinary evaluation preoperatively and long-term follow-up after surgery. Studies are divided as to whether bariatric surgery can provide cost savings, although most authors agree that surgery is cost-effective in terms of quality-adjusted life-years.[16–24] Among studies looking specifically at patients with type 2 diabetes, findings are equally mixed.[17,18,20,24,25]

More than half of the estimated direct health costs of type 2 diabetes relate to drug costs.[1] Several studies have shown a reduction in hypoglycemic medication use following bariatric surgery.[26–29] Such a reduction in the requirement for medication can result in significant cost savings for patients and health care systems.

It is estimated that the economic burden of diabetes in Manitoba will reach $639 million by 2020.[30] The Winnipeg Regional Health Authority established a multidisciplinary bariatric surgery program in 2010, and more than 1000 bariatric procedures have been completed to date. The primary aim of this project was to determine the effect of Roux-en-Y gastric bypass (RYGB) on the use of insulin and oral hypoglycemic therapy in a population of obese patients with type 2 diabetes. The secondary objective was to estimate cost savings per patient related to diabetes management using local cost estimates.

Methods

After ethics board review and approval, we reviewed the bariatric clinic records of all patients with a confirmed diagnosis of type 2 diabetes who underwent RYGB at Victoria General Hospital, a 230-bed hospital in Winnipeg, over a 5-year period (2010/11–2014/15). Patients were identified from a prospectively maintained bariatric database. Patients with type 1 diabetes were excluded from the study. All patients undergoing bariatric surgery are enrolled in a behavioural modification program before surgery that includes nutrition, activity and psychosocial counselling. All the procedures over the study period were performed by a team of 3 bariatric surgeons.

Inclusion criteria included a preoperative diagnosis of type 2 diabetes and having undergone RYGB with a minimum of 12 months of complete follow-up data. A diagnosis of type 2 diabetes was defined as a documented pretreatment glycated hemoglobin (HbA_{1c}) level greater than 6.5% or the use of hypoglycemic medication (orally administered or insulin).

The following data were extracted: age, sex, length of time between diabetes diagnosis and surgery, BMI, HbA_{1c} level, and number and type of hypoglycemic medications preoperatively and 12 months following surgery. We expressed postoperative weight loss using the postoperative BMI and the percentage estimated weight loss using a BMI of 25 as the ideal body weight. Body mass index was calculated as close to the time of surgery as possible and several months after the patients had started their preoperative interventions. Postoperative BMI was recorded at 12 months. Perioperative HbA_{1c} was taken as close as possible to the time of surgery and then at the 12-month follow-up visit. Remission of diabetes was predefined as an HbA_{1c} level of 6.5% or less and the patient's having ceased all antidiabetic medications.

We estimated medication costs using Manitoba-specific pricing data,[31] assuming a standard dosage of medication. Insulin dosage was not known for individual patients, and therefore we assumed a conservative starting dosage of 25 units/d based on Canadian guidelines.[32]

We performed an analysis of long-term cost savings using estimates of type 2 diabetes prevalence and estimated direct and indirect costs in Manitoba calculated by Diabetes Canada.[30] Diabetes Canada estimates yearly costs of $5298 per patient with diabetes. For the purposes of the model, we assumed that any patient not achieving remission (i.e., still receiving at least 1 hypoglycemic medication or HbA_{1c} level > 6.5% at 12 mo postoperatively) would continue to generate health care costs at that level. Similarly, patients who achieved remission but were predicted to subsequently relapse were assumed to generate yearly costs of $5298 from the time of relapse. Patients in remission were assumed to generate no diabetes-related costs. In extrapolating these cost savings forward, we estimated that the relapse rate would be 6% of patients per year.[14,15]

We used StatsDirect version 3.0.141 to analyze the data. We analyzed differences between pre- and postoperative variables using the paired *t* test (normal data) or the

Mann–Whitney test (nonnormal data) and compared categorical variables using the Fisher exact test. A p value < 0.05 was considered statistically significant.

Results

Fifty-two patients who underwent RYGB and had at least 12 months of complete follow-up data were identified. Most of the patients (43 [83%]) were women. The mean BMI decreased from 44.8 (33.6–58.2) preoperatively to 33.5 (range 21.0–47.5) at 1 year. This represented a mean percentage estimated weight loss of 50.2%. The mean HbA_{1c} level decreased from 7.6% (range 4.9%–12.1%) to 6.0% (range 4.5%–8.2%) ($p < 0.001$). The mean number of orally administered hypoglycemics declined from 1.6 to 0.2 ($p < 0.001$), and the number of patients receiving insulin decreased from 18 (35%) to 3 (6%) ($p < 0.001$).

At 12 months, 37 patients (71%) had achieved resolution of type 2 diabetes. The remaining 15 patients (29%) all had improvements in HbA_{1c} level compared to preoperative levels (mean 7.1% v. 8.7%). In addition, their mean number of orally administered hypoglycemic agents decreased from 2.6 to 1.1, and the number receiving insulin decreased from 11 (73%) to 3 (20%).

The patients who achieved remission and those who did not were similar in age, sex and preoperative BMI (Table 1). Compared to patients who did not achieve remission, those who achieved remission had lower preoperative HbA_{1c} levels (mean 7.2% v. 8.7%, $p = 0.01$), required fewer hypoglycemic agents preoperatively (mean 1.8 v. 2.5, $p = 0.02$) and were less likely to be receiving insulin therapy preoperatively (7 [19%] v. 11 [73%], $p < 0.001$). Patients whose diabetes resolved had a significantly shorter duration of diabetes preoperatively (4.0 yr v. 6.1 yr, $p < 0.001$). The percentage estimated weight loss was not significantly different between the 2 groups (52.0% v. 45.6%, $p = 0.3$).

Table 1. Preoperative characteristics of patients who achieved or did not achieve remission of type 2 diabetes mellitus at 12 months after Roux-en-Y gastric bypass

	No. (%) of patients*		
Characteristic	Remission $n = 37$	No remission $n = 15$	p value
Age, yr, mean ± SD	48.5 ± 7.38	49.1 ± 5.99	0.8†
Female sex	32 (86)	11 (73)	0.3‡
Preoperative body mass index, mean ± SD	44.6 ± 5.35	45.4 ± 6.48	0.7†
Preoperative glycated hemoglobin level, %, mean ± SD	7.2 ± 1.48	8.7 ± 1.81	0.01†
No. of medications, mean ± SD	1.8 ± 0.83	2.5 ± 0.81	0.02§
Insulin use	7 (19)	11 (73)	< 0.001‡

SD = standard deviation.
*Except where noted otherwise.
†Unpaired t test.
‡Fisher exact test.
§Mann–Whitney test.

The mean length of stay was 1.3 (standard deviation 0.6) days. Complications were identified in 4 patients (8%). In 1 patient, an ulcer developed at the gastrojejunostomy. This was seen on endoscopy, which was performed for patient symptoms. The patient was treated with omeprazole (20 mg twice daily) and sucralfate (1 g 4 times daily), with endoscopic resolution documented at 6 weeks. One patient required a transfusion of 1 unit of packed red blood cells owing to symptomatic anemia on postoperative day 1. Two patients required readmission for nausea, liquid intolerance and upper abdominal pain; both were managed conservatively with analgesia and supportive care and were discharged the day after presenting.

We estimated that mean annual hypoglycemic medication costs per patient decreased from $508.56 preoperatively to $79.17 at 12 months ($p < 0.001$). Even among the patients who remained diabetic, we estimated that mean annual medication costs decreased ($856.30 v. $274.46, $p < 0.001$).

Based on our analysis of cost savings and on local estimates of the cost of diabetes,[30] assuming a relapse rate of 6% per year, we estimated savings to the health care system of $3769 per patient in the first year, declining to $2865 and $1734 at 5 and 10 years, respectively. Lifetime savings per patient could total $33 324. Doubling the relapse rate to 12% would still result in a potential lifetime saving of $17 642 per patient. In comparison, the estimated per-patient cost of RYGB in our unit at the time of study was $5989 (includes the cost of the preoperative behavioural modification program, the operation and routine postoperative care).

Discussion

Type 2 diabetes represents a large and ever-growing burden on health care systems around the world. There is currently little evidence available regarding the effect of laparoscopic RYGB on the use of diabetic medications in obese people with type 2 diabetes. This is despite the large increase in bariatric surgical procedures throughout the country over the last decade.[33] The cost to the Canadian taxpayer of performing bariatric surgery in Canada was estimated at $48 million in 2012/13.[33] It is important, therefore, that the cost-effectiveness of such an intervention be determined.

Our results in a cohort of patients who underwent laparoscopic RYGB support previous findings that bariatric surgery is highly effective at instigating both weight loss and diabetic remission. Seventy-one percent of patients were in remission at 1 year. Just as important, patients who did not achieve remission still experienced significant reductions in both HbA_{1c} level and medication requirements. Our results support the findings of other authors who have noted that remission is more likely in patients with a shorter preoperative duration of diabetes and lower preoperative HbA_{1c} levels and in those not requiring insulin.[34–36]

Based on these results, we estimate that diabetes-related medication costs decrease significantly within the first year after surgery ($508.56 to $79.17 per patient). Extrapolating potential cost savings forward, we estimate potential lifetime savings of $33 324 per patient. In comparison, the cost per procedure in our unit is estimated at $5989.

These results are consistent with those of other studies that have shown similarly significant reductions in the requirement for diabetic medications and resultant cost savings.[25,29,37,38] Similar reductions in medication use have been reported for other conditions such as hypertension and dyslipidemia.[29,37,39,40]

The evidence that bariatric surgery can provide long-term clinical benefits to patients with diabetes is well established.[10–14] In addition, there is substantial evidence to support the overall cost-effectiveness of surgery in the bariatric population.[17–19,23,41] However, it is important to recognize the difference between cost-effectiveness, usually assessed using evaluation of quality-adjusted life-years,[42] and the ability of an intervention to realize cost savings for a health care system.

Long-term follow-up from the Swedish Obese Subjects study showed that drug costs were lower in patients with diabetes who underwent bariatric surgery than in those in a control group.[21] However, the study did not show differences in overall health care costs. Similarly, in a large study based in the United States, Weiner and colleagues[43] compared a surgical group with a matched nonsurgical group of obese patients and concluded after 6 years of follow-up that there was no overall reduction in health care costs. In contrast, Swedish and Spanish studies based on simulation models showed large long-term cost savings along with increased quality-adjusted life-years.[44,45]

It should be noted, however, that many of the studies with long-term follow-up provide data on historical procedures. For example, only a small proportion of patients in the Swedish Obese Subjects study[21] underwent laparoscopic RYGB; the majority underwent a restrictive procedure (gastric band or vertical banded gastroplasty). Both of these procedures have been largely abandoned because of their reduced efficacy.[46] Similarly, in the study by Weiner and colleagues,[43] only 38.3% of patients underwent laparoscopic RYGB, with the remainder receiving open RYGB or a restrictive procedure. These procedures are not necessarily relevant to modern-day practice, where laparoscopic RYGB and laparoscopic sleeve gastrectomy are the most commonly performed procedures.[46] Cremieux and colleagues[16] compared costs between patients undergoing open and laparoscopic surgery and found that it took twice as long to recoup the costs of surgery in the open surgery group as in the laparoscopic group.

The variation in results between studies may be due to the fact that a variety of methodologies were used, and it is notable that studies based on prediction models tend to overestimate cost savings compared to studies looking at actual, recordable costs.[21,25,43,44] In addition, studies performed in different countries are likely to result in different outcomes owing to differences in health care systems. Studies from the United Kingdom tend not to show absolute cost savings,[18,19,41,43,47] whereas studies from elsewhere show mixed but generally more positive results.[20,22,44,45,48]

We used a predicted relapse rate of 6% in our model. This is consistent with that reported in the literature.[7,8,14,49] The relapse rate among postsurgical patients with diabetes in Canada is not known, and, clearly, higher relapse rates would result in our model's overestimating cost savings. We were not able to report our relapse rates for type 2 diabetes owing to local data set limitations. However, our results suggest that even a doubling of the relapse rate may still result in substantial cost savings. Longer-term data are required to establish these trends, but, as shown in our study and others, even patients not achieving remission experience significant improvements. Therefore, it is likely that, even without resolution of diabetes, improved control and therefore further delay of complications should be expected.[8,14]

Limitations

Some limitations to this study should be noted. Our analysis represents a small sample of patients and is limited to those with 1 year of follow-up data. It is possible that patients failing to attend follow-up visits experience poorer outcomes. The estimates for total health care savings presented in this study rely on predicted data extrapolated forward. This is a fairly rudimentary method for predicting costs and is clearly less reliable than direct, observable measurements of cost. In particular, there are a number of limitations to the cost-prediction model. Our analysis did not take into account other factors such as life expectancy or patient age. Overall mortality is low after bariatric surgery and is therefore unlikely to have a substantial effect on costs.

Furthermore, unlike in studies from larger centres,[21,43–45] the model did not factor in the health-related costs of complications. Additional health costs should not substantially affect the findings for our cohort as the complication rate happened to be low in this patient sample. It is assumed that a larger data set would yield complication rates similar to those of the general bariatric surgical population. Thus, costs should be similar to those in the literature, as the study centre's overall complication rate is in line with international trends. We hope to be able to further evaluate this in our own database when resources permit.

The model used in this investigation was intentionally conservative and likely underestimated cost savings. It assumed that patients not achieving remission and those who relapse will generate the same mean health care costs as nonsurgical patients with diabetes. Given the observed improvements in metabolic markers, this is unlikely to be the case. We do make the assumption that patients in remission generate no ongoing diabetes-related health care costs. We accept that this is a potential underestimate, but the same assumption is made in other bariatric surgery cost-analysis models,[18] and in the absence of long-term data on the cost-related impact of bariatric surgery on micro- and macrovascular complications, we believe this is reasonable. In addition, we do not consider other, potential cost savings not related to health care. Studies have shown that patients have better employment prospects and claimed significantly fewer benefits following surgery.[50,51]

Finally, the Diabetes Canada analysis[30] used for the costs analysis includes patients with type 1 diabetes as well as those with type 2 diabetes. This has the potential to influence our results, as the former are usually receiving costlier, insulin-based therapies. However, the proportion of patients with type 1 diabetes is likely to be small and therefore should not unduly influence the overall cost estimate.

Conclusion

Roux-en-Y gastric bypass results in significant glycemic improvement in obese patients with type 2 diabetes. This improvement results in a measurable reduction in hypoglycemic medication use and associated costs in the early postoperative period. Potentially, large indirect and direct cost savings can be realized in the longer term. Larger, long-term studies using robust costing methods are required to further refine these results.

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Contributors: All authors designed the study. M. Mullan and A. Vergis acquired the data, which A. Sharples, K. Hardy and A. Vergis analyzed. A. Sharples, M. Mullan and A. Vergis wrote the article, which all authors reviewed and approved for publication.

References

1. 2015 report on diabetes — driving change. Toronto: Diabetes Canada; 2015.
2. Diabetes in Canada: facts and figures from a public health perspective. Ottawa: Public Health Agency of Canada; 2011.
3. Saydah SH, Fradkin J, Cowie CC. Poor control of risk factors for vascular disease among adults with previously diagnosed diabetes. *JAMA* 2004;291:335-42.
4. Stark Casagrande S, Fradkin JE, Saydah SH, et al. The prevalence of meeting A_{1c}, blood pressure, and LDL goals among people with diabetes, 1988–2010. *Diabetes Care* 2013;36:2271-9.
5. Dorman RB, Serrot FJ, Miller CJ, et al. Case-matched outcomes in bariatric surgery for treatment of type 2 diabetes in the morbidly obese patient. *Ann Surg* 2012;255:287-93.
6. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA* 2004;292:1724-37.
7. Schauer PR, Kashyap SR, Wolski K, et al. Bariatric surgery versus intensive medical therapy in obese patients with diabetes. *N Engl J Med* 2012;366:1567-76.
8. Sjöström L, Peltonen M, Jacobson P, et al. Association of bariatric surgery with long-term remission of type 2 diabetes and with microvascular and macrovascular complications. *JAMA* 2014;311:2297-304.
9. Yska JP, van Roon EN, de Boer A, et al. Remission of type 2 diabetes mellitus in patients after different types of bariatric surgery: a population-based cohort study in the United Kingdom. *JAMA Surg* 2015;150:1126-33.
10. Sjöström L, Lindroos AK, Peltonen M, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med* 2004;351:2683-93.
11. Sjöström L, Narbro K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med* 2007;357:741-52.
12. Chen Y, Corsino L, Shantavasinkul PC, et al. Gastric bypass surgery leads to long-term remission or improvement of type 2 diabetes and significant decrease of microvascular and macrovascular complications. *Ann Surg* 2016;263:1138-42.
13. Mingrone G, Panunzi S, De Gaetano A, et al. Bariatric–metabolic surgery versus conventional medical treatment in obese patients with type 2 diabetes: 5 year follow-up of an open-label, single-centre, randomised controlled trial. *Lancet* 2015;386:964-73.
14. Schauer PR, Bhatt DL, Kirwan JP, et al. Bariatric surgery versus intensive medical therapy for diabetes — 5-year outcomes. *N Engl J Med* 2017;376:641-51.
15. An economic tsunami: the cost of diabetes in Canada. Toronto: Diabetes Canada; 2009.
16. Cremieux PY, Buchwald H, Shikora SA, et al. A study on the economic impact of bariatric surgery. *Am J Manag Care* 2008;14:589-96.
17. Ikramuddin S, Klingman D, Swan T, et al. Cost-effectiveness of Roux-en-Y gastric bypass in type 2 diabetes patients. *Am J Manag Care* 2009;15:607-15.
18. Hoerger TJ, Zhang P, Segel JE, et al. Cost-effectiveness of bariatric surgery for severely obese adults with diabetes. *Diabetes Care* 2010;33:1933-9.
19. Salem L, Devlin A, Sullivan SD, et al. Cost-effectiveness analysis of laparoscopic gastric bypass, adjustable gastric banding, and nonoperative weight loss interventions. *Surg Obes Relat Dis* 2008;4:26-32.
20. Keating CL, Dixon JB, Moodie ML, et al. Cost-effectiveness of surgically induced weight loss for the management of type 2 diabetes: modeled lifetime analysis. *Diabetes Care* 2009;32:567-74.
21. Keating C, Neovius M, Sjöholm K, et al. Health-care costs over 15 years after bariatric surgery for patients with different baseline glucose status: results from the Swedish Obese Subjects study. *Lancet Diabetes Endocrinol* 2015;3:855-65.
22. Bruschi Kelles SM, Machado CJ, Barreto SM. Before-and-after study: Does bariatric surgery reduce healthcare utilization and related costs among operated patients? *Int J Technol Assess Health Care* 2015;31:407-13.
23. Clegg A, Colquitt J, Sidhu M, et al. Clinical and cost effectiveness of surgery for morbid obesity: a systematic review and economic evaluation. *Int J Obes Relat Metab Disord* 2003;27:1167-77.
24. Bleich SN, Chang HY, Lau B, et al. Impact of bariatric surgery on health care utilization and costs among patients with diabetes. *Med Care* 2012;50:58-65.
25. Makary MA, Clark JM, Shore AD, et al. Medication utilization and annual health care costs in patients with type 2 diabetes mellitus before and after bariatric surgery. *Arch Surg* 2010;145:726-31.
26. Cremieux PY, Ledoux S, Clerici C, et al. The impact of bariatric surgery on comorbidities and medication use among obese patients. *Obes Surg* 2010;20:861-70.
27. Hodo DM, Waller JL, Martindale RG, et al. Medication use after bariatric surgery in a managed care cohort. *Surg Obes Relat Dis* 2008;4:601-7.

28. Nguyen NT, Varela JE, Sabio A, et al. Reduction in prescription medication costs after laparoscopic gastric bypass. *Am Surg* 2006;72:853-6.
29. Gesquiere I, Aron-Wisnewsky J, Foulon V, et al. Medication cost is significantly reduced after Roux-en-Y gastric bypass in obese patients. *Obes Surg* 2014;24:1896-903.
30. The cost of diabetes in Manitoba. Toronto: Diabetes Canada; 2009.
31. Price comparison of commonly prescribed medications in Manitoba. 2nd ed. 2017. Available: https://medsconference.files.wordpress.com/2017/02/price_comparison_of_common_rx_drugsmb-2017.pdf (accessed 2018 Feb. 12).
32. Canadian Diabetes Association Clinical Practice Guidelines Expert Committee, Harper W, Clement M, Goldenberg R, et al. Pharmacologic management of type 2 diabetes. *Can J Diabetes* 2013;37(Suppl 1): S61-8.
33. Bariatric surgery in Canada. Ottawa: Canadian Institute for Health Information; 2014.
34. Robert M, Ferrand-Gaillard C, Disse E, et al. Predictive factors of type 2 diabetes remission 1 year after bariatric surgery: impact of surgical techniques. *Obes Surg* 2013;23:770-5.
35. Zenti MG, Rubbo I, Ceradini G, et al. Clinical factors that predict remission of diabetes after different bariatric surgical procedures: interdisciplinary group of bariatric surgery of Verona (G.I.C.O.V.). *Acta Diabetol* 2015;52:937-42.
36. Wang GF, Yan YX, Xu N, et al. Predictive factors of type 2 diabetes mellitus remission following bariatric surgery: a meta-analysis. *Obes Surg* 2015;25:199-208.
37. Segal JB, Clark JM, Shore AD, et al. Prompt reduction in use of medications for comorbid conditions after bariatric surgery. *Obes Surg* 2009;19:1646-56.
38. Schauer PR, Burguera B, Ikramuddin S, et al. Effect of laparoscopic Roux-en-Y gastric bypass on type 2 diabetes mellitus. *Ann Surg* 2003;238:467-84; discussion 84-5.
39. Athyros VG, Tziomalos K, Karagiannis A, et al. Cardiovascular benefits of bariatric surgery in morbidly obese patients. *Obes Rev* 2011; 12:515-24.
40. Heneghan HM, Meron-Eldar S, Brethauer SA, et al. Effect of bariatric surgery on cardiovascular risk profile. *Am J Cardiol* 2011;108: 1499-507.
41. Craig BM, Tseng DS. Cost-effectiveness of gastric bypass for severe obesity. *Am J Med* 2002;113:491-8.
42. Owens DK. Interpretation of cost-effectiveness analyses. *J Gen Intern Med* 1998;13:716-7.
43. Weiner JP, Goodwin SM, Chang HY, et al. Impact of bariatric surgery on health care costs of obese persons: a 6-year follow-up of surgical and comparison cohorts using health plan data. *JAMA Surg* 2013;148:555-62.
44. Borisenko O, Adam D, Funch-Jensen P, et al. Bariatric surgery can lead to net cost savings to health care systems: results from a comprehensive European decision analytic model. *Obes Surg* 2015;25: 1559-68.
45. Castilla I, Mar J, Valcarcel-Nazco C, et al. Cost-utility analysis of gastric bypass for severely obese patients in Spain. *Obes Surg* 2014;24: 2061-8.
46. Angrisani L, Santonicola A, Iovino P, et al. Bariatric surgery worldwide 2013. *Obes Surg* 2015;25:1822-32.
47. Maciejewski ML, Smith VA, Livingston EH, et al. Health care utilization and expenditure changes associated with bariatric surgery. *Med Care* 2010;48:989-98.
48. Ackroyd R, Mouiel J, Chevallier JM, et al. Cost-effectiveness and budget impact of obesity surgery in patients with type-2 diabetes in three European countries. *Obes Surg* 2006;16:1488-503.
49. Arterburn DE, Bogart A, Sherwood NE, et al. A multisite study of long-term remission and relapse of type 2 diabetes mellitus following gastric bypass. *Obes Surg* 2013;23:93-102.
50. Sharples AJ, Cheruvu CV. Systematic review and meta-analysis of occupational outcomes after bariatric surgery. *Obes Surg* 2017;27: 774-81.
51. Hawkins SC, Osborne A, Finlay IG, et al. Paid work increases and state benefit claims decrease after bariatric surgery. *Obes Surg* 2007; 17:434-7.