The Effects of Gastric Bypass Surgery on Type II Diabetes Mellitus

Melissa Balogh

Recommended Citation
Balogh, Melissa, "The Effects of Gastric Bypass Surgery on Type II Diabetes Mellitus" (2010). School of Physician Assistant Studies. 255.
https://commons.pacificu.edu/pa/255

This Capstone Project is brought to you for free and open access by the College of Health Professions at CommonKnowledge. It has been accepted for inclusion in School of Physician Assistant Studies by an authorized administrator of CommonKnowledge. For more information, please contact CommonKnowledge@pacificu.edu.
The Effects of Gastric Bypass Surgery on Type II Diabetes Mellitus

Abstract

Background: Over 240 million people worldwide are affected by type II diabetes, and this number is expected to rise to over 380 million by the year 2025. As type II diabetes becomes exponentially more prevalent in our society, novel treatment options should be explored. Currently, the management of type II diabetes focuses on the prevention of disease progression through lifestyle modifications and medical therapy. Although there have been advances in the pharmacological treatment of type II diabetes, it still remains a poorly controlled disease. Emerging data suggest that bariatric surgery may provide a more sustained and effective treatment for type II diabetes.

Method: An extensive search of the literature using MEDLINE, PUBMED, UPTODATE and CINAHL were performed to identify the effects of gastric bypass surgery on type II diabetes for the purpose of performing a systematic review and assessing the outcomes using the GRADE system. Two randomized control trials, and one cohort study were identified.

Results: Based on the two randomized control trials and one cohort study, showed that the efficacy of gastric bypass surgery was significantly greater than diet and medication without surgery, in the treatment of type II diabetes in terms of reducing HbA1C and fasting plasma glucose.

Conclusion: Overall, the use of gastric bypass surgery in the treatment of type II diabetes significantly reduces HbA1c, fasting plasma glucose and the use of pharmacotherapy. This review of the outcomes using the GRADE system confirms the effectiveness of bariatric surgery as a therapy for type II diabetes.

Keywords: type 2 diabetes, gastric bypass

Degree Type
Capstone Project

Degree Name
Master of Science in Physician Assistant Studies

First Advisor
Torry Cobb

Second Advisor
Any Hill

Keywords
type 2 diabetes, gastric bypass

Subject Categories
Medicine and Health Sciences

This capstone project is available at CommonKnowledge: https://commons.pacificu.edu/pa/255
Copyright and terms of use

If you have downloaded this document directly from the web or from CommonKnowledge, see the “Rights” section on the previous page for the terms of use.

If you have received this document through an interlibrary loan/document delivery service, the following terms of use apply:

Copyright in this work is held by the author(s). You may download or print any portion of this document for personal use only, or for any use that is allowed by fair use (Title 17, §107 U.S.C.). Except for personal or fair use, you or your borrowing library may not reproduce, remix, republish, post, transmit, or distribute this document, or any portion thereof, without the permission of the copyright owner. [Note: If this document is licensed under a Creative Commons license (see “Rights” on the previous page) which allows broader usage rights, your use is governed by the terms of that license.]

Inquiries regarding further use of these materials should be addressed to: CommonKnowledge Rights, Pacific University Library, 2043 College Way, Forest Grove, OR 97116, (503) 352-7209. Email inquiries may be directed to: copyright@pacificu.edu
NOTICE TO READERS

This work is not a peer-reviewed publication. The Master’s Candidate author of this work has made every effort to provide accurate information and to rely on authoritative sources in the completion of this work. However, neither the author nor the faculty advisor(s) warrants the completeness, accuracy or usefulness of the information provided in this work. This work should not be considered authoritative or comprehensive in and of itself and the author and advisor(s) disclaim all responsibility for the results obtained from use of the information contained in this work. Knowledge and practice change constantly, and readers are advised to confirm the information found in this work with other more current and/or comprehensive sources.

The student author attests that this work is completely his/her original authorship and that no material in this work has been plagiarized, fabricated or incorrectly attributed.
The Effects of Gastric Bypass Surgery on Type II Diabetes Mellitus

Melissa Balogh

A course paper presented to the College of Health Professions in partial fulfillment of the requirements of the degree of Master of Science

Pacific University School of Physician Assistant Studies

December, 2010

Faculty Advisor: Professor Cobb
Clinical Graduate Project Instructors: Torry Cobb, DHSc, MPH, PA-C & Annjanette Sommers MS, PAC
Biography

Melissa Balogh is a native of Boulder, CO where she attended Colorado State University and completed her Bachelor of Science in Biology with a minor in Biomedical Sciences. After completion of her undergraduate degree, she worked as a Research Assistant on West Nile Virus for the CDC in Fort Collins, CO for three years. She then worked for National Jewish Hospital in Denver, CO as a Research assistant in the Pediatric Allergy department as well as the University of Colorado’s Hospital as a phlebotomy and EKG technician. Wanting to advance her career, she is pursuing a Masters in Physician Assistant Studies and is expected to graduate in the Summer of 2011.

Acknowledgements

To my family: Thank you for helping me to succeed and for supporting me in my chosen endeavors.

To my friends: Many thanks for all the great laughs.
ABSTRACT

**Background:** Over 240 million people worldwide are affected by type II diabetes, and this number is expected to rise to over 380 million by the year 2025. As type II diabetes becomes exponentially more prevalent in our society, novel treatment options should be explored. Currently, the management of type II diabetes focuses on the prevention of disease progression through lifestyle modifications and medical therapy. Although there have been advances in the pharmacological treatment of type II diabetes, it still remains a poorly controlled disease. Emerging data suggest that bariatric surgery may provide a more sustained and effective treatment for type II diabetes.

**Method:** An extensive search of the literature using MEDLINE, PUBMED, UPTODATE and CINAHL were performed to identify the effects of gastric bypass surgery on type II diabetes for the purpose of performing a systematic review and assessing the outcomes using the GRADE system. Two randomized control trials, and one cohort study were identified.

**Results:** Based on the two randomized control trials and one cohort study, showed that the efficacy of gastric bypass surgery was significantly greater than diet and medication without surgery, in the treatment of type II diabetes in terms of reducing HbA1C and fasting plasma glucose.

**Conclusion:** Overall, the use of gastric bypass surgery in the treatment of type II diabetes significantly reduces HbA1C, fasting plasma glucose and the use of pharmacotherapy. This review of the outcomes using the GRADE system confirms the effectiveness of bariatric surgery as a therapy for type II diabetes.

**Keywords:** type 2 diabetes, gastric bypass
TABLE OF CONTENTS

INTRODUCTION ............................................................................................................. 5
   Background ............................................................................................................... 5
   Purpose of the Study ................................................................................................. 7
METHOD ......................................................................................................................... 7
RESULTS ........................................................................................................................ 8
DISCUSSION................................................................................................................. 13
CONCLUSION……………………………………………………………………… ............... 17
REFERENCES .............................................................................................................. 18
APPENDIX ..................................................................................................................... 19
   .....A: GRADE Table........................................................................................................ 20
   .....B: Table 1 Baseline Characteristics of Participants.................................................. 21
   .....C: Table 2 Primary and Secondary Outcomes at 2 years......................................... 22
   .....D: Table 3 Effect of Gastric Bypass on the glucose metabolism.............................. 23
   .....E: Table 4 HOMA Index, Glucose and Fasting Insulin Before, and 1 week and
   3 months postoperatively after LRYGB: Mean +/- SD and (Range)............................ 24
   .....F: Table 5 HOMA index, Glucose and Fasting Insulin Before, and 1 weeks and
   3 months postoperatively after LSG: Mean +/- SD and (Range)......................... 25

INTRODUCTION
Background

Type II diabetes mellitus is a major endocrine disorder that is characterized by the development of insulin resistance and a progressive reduction in insulin secretion by the pancreas. The development of type II diabetes is strongly associated with obesity and the accumulation of abdominal and ectopic fat. These fat deposits have been linked to peripheral and hepatic insulin resistance, inflammation and subsequent toxicity of β-cells. Approximately 240 million people are currently afflicted with type II diabetes, and the number is expected to exceed 380 million by the year 2025 (Rubino, Kaplan, Schauer, Cummings, 2010). As type II diabetes becomes exponentially more prevalent in our society, novel treatment options should be explored.

Currently, the management of type II diabetes focuses on the prevention of disease progression through lifestyle modifications and medical therapy. Although there have been tremendous advances in the pharmacological treatment of type II diabetes, it still remains a poorly controlled disease. Emerging data suggest that bariatric surgery may provide a more sustained and effective treatment for obesity and related morbidities such as hyperglycemia and type II diabetes. Initial reports indicate that improved control of type II diabetes could be seen a few weeks to months after surgery. Recently it has been seen that these improvements may take place much soon after surgery and before weight loss has even taken place (Wickremesekera, Miller, Naotunne, Knowles & Stubbs, 2005). Several hypotheses for this have been proposed but regardless of
the mechanism, endeavors to find more effective therapies for type II diabetes should be explored.

Bariatric surgery procedures are divided into three categories: malabsorptive, restrictive and combined malabsorptive and restrictive. Malabsorptive procedures develop weight loss by decreasing nutrient absorption due to small intestine shortening (Spanakis & Gragnoli, 2009). These procedures have been limited due to increased mortality and complications. Gastric restrictive surgeries including the laparoscopic adjustable gastric band (LAGB) and laparoscopic sleeve gastrectomy (LSG) restrict stomach capacity to limit the intake of solid food and calories. The most common type of bariatric surgery done today is the roux-en-y bypass (RYGB), which is both malabsorptive and restrictive. In a RYGB, the stomach is made smaller by creating a small pouch at the top of the stomach using surgical staples or a plastic band. The smaller stomach is then connected directly to the middle portion of the small intestine (jejunum), bypassing the rest of the stomach and the upper portion of the small intestine (duodenum).

There is now considerable evidence that operations previously performed as weight loss procedures, are able to induce long-term diabetes remission in most cases. The Roux en y gastric bypass (RYGB) demonstrated an 83.7% resolution of diabetes compared with restrictive procedures such as the laparoscopically adjustable gastric band (LAGB) which achieves a 47.9% resolution (Moo & Rubino, 2008). The concept of complete and long-term diabetes remission is demonstrated in the normalization of blood glucose levels,
insulin, HbA1c and the discontinuation of diabetes medications. If the antidiabetic effect of gastrointestinal bypass procedures is not unique to the obese population and the mechanism appears to be independent of weight loss and caloric intake, it becomes evident that gastrointestinal bypass surgery can no longer be seen solely as a therapy for obesity (Moo & Rubino, 2008). This supports the new concept of diabetes surgery, one in which a surgical intervention is intentionally used to treat diabetes.

**Purpose of the Study**

As the incidence of type II diabetes continues to rise worldwide at epidemic proportions, endeavors to find more effective therapies increase. Gastrointestinal bypass surgery is now gaining awareness as a potentially effective and long-term treatment. The purpose of this paper is to conduct a systematic review of gastrointestinal bypass surgery on the glycemic control and insulin resistance of type II diabetes and to analyze the outcomes using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.

**METHOD**

An extensive literature search was performed using Medline. This database was accessed through the Pacific University Library system. The keywords searched were “bariatric surgery” and “diabetes mellitus, type 2” individually and in combination. The search was limited to human subjects, full text, English language and evidence based medicine reviews. Articles older than
three years were excluded. The initial results included 8 articles. Of the 8 articles, only one article was a randomized controlled trial directly comparing gastric banding and conventional therapy and was selected for review.

Another extensive literature search was performed using Pubmed. The keywords searched were “glucose metabolism” “type 2 diabetes” and “bariatric surgery” individually and in combination. The search was limited to human subjects, full text and English language. Articles older than five years were excluded as well as articles that did not appear to be relevant to the topic. The initial results included 3 articles. Two articles were excluded because they were reviews and the remaining article was included.

Another literature search was performed using Uptodate. The keywords searched were “roux en y” individually. An article titled “Surgical management of severe obesity” was perused and found to have a section on treatment for type II diabetes. The articles that were cited in this section were sought out using Medline using their respective title and author. This resulted in one randomized control trial. A total of three articles were selected for review.

RESULTS

From the years 2005-2010, there were a total of three published articles that discussed gastric bypass surgery and the positive effects it had on controlling type II diabetes mellitus in terms of improving glycemic control and increasing insulin sensitivity. The three studies all used fasting plasma glucose and HbA1c as pre and post-operative markers of diabetic improvement. Two of the studies also used the Homeostasis Model Assessment – insulin resistance
(HOMA-ir) index, both pre and postoperatively, as well as plasma insulin levels. The HOMA index is derived from fasting plasma glucose and insulin levels and is an excellent way to assess insulin resistance.

Dixon, O’Brien, Playfair and Chapman (2008), studied the effects of adjustable gastric banding (AGB) and conventional therapy (CT) on type II diabetes. Recruitment commenced in December 2002, and all data was available for analysis in December 2006. This study was a randomized control trial that allocated sixty patients into two treatment groups. Thirty patients received CT (diet/exercise), and thirty patients received laparoscopic AGB. One patient randomized to surgery withdrew from the study on the evening prior to the scheduled operation and didn’t agree to further follow up. The remaining twenty-nine surgically treated patients completed the two-year program. Of the conventionally treated patients, twenty-six completed the two-year assessment.

Pre-operatively in the surgical group, the mean HbA1c levels were 7.8%, plasma glucose levels were 156.7 and plasma insulin levels were 19.7, and in the CT group it was 7.6%, 158.0 and 18.7, respectively (Table 1, Appendix B).

Remission of type 2 diabetes was achieved by twenty six participants at two years (73%) randomized to the surgical program and four (13%) to the conventional therapy program (p<.001). This represented 76% and 15% remission rates among those who completed the follow-up in the surgery and conventional therapy groups. Mean levels of HbA1c, fasting plasma glucose and insulin levels were significantly lower in the surgical group at two years. HbA1c levels were 6.0% with a decrease of 1.81, plasma glucose levels were 105.6 with
a decrease of 51.2, and plasma insulin levels were 9.8 with a decrease of 12.4 (Table 2, Appendix C). The CT group had HbA1c levels at 7.21% with a decrease of 0.38, plasma glucose levels were 139.6 with a decrease of 18.4 and plasma insulin levels were 24.1 with an increase of 1.0 (Table 2, Appendix C). Insulin resistance was calculated preoperatively and again at the two-year follow up. The HOMA-ir score was 1.90 in the surgical group with a decrease of 45.5, and in the CT group it was 3.50 with a decrease of 3.3 (Table 2, Appendix C). Of these results, the HbA1c, plasma glucose, plasma insulin and HOMA-ir were statistically significant with a p-value<0.05. The HbA1c had a p-value<.001 with a 95% CI (-2.1 to -0.80). The plasma glucose had a p-value=.002 with a 95% CI (-53.1 to -12.3). The plasma insulin had a p-value<.001 with a 95% CI ( -19.6 to -7.3), and the HOMA-ir had a p-value<.001 with a 95% CI (-57 to -26.8). There was also a significant reduction in the use of pharmacotherapy for glycemic control in the surgical group at two years. At baseline, two surgically treated and four conventionally treated were not using pharmacotherapy; at two years, the numbers were twenty-six and eight, respectively. In the surgical group at two years there were fewer using metformin (3 vs. 28, P<.001) and other hypoglycemic therapy (1 vs. 9, p=0.006). The one surgical patient using insulin at baseline was in remission at two years. There were no significant changes in the use of therapy in the group randomized to receive conventional therapy.

Torquati, Lutfi, Abumrad and Richards (2005), studied whether or not the roux-en-y gastric bypass (RYGB) was the most effective treatment for type II diabetes mellitus in morbidly obese patients. This study was a prospective cohort
that was conducted at Vanderbilt University Medical Center that enrolled 117 consecutive patients over a thirty-month period who were morbidly obese with type II diabetes who were undergoing laparoscopic RYGB. The primary outcome measured was the resolution of type II diabetes and the secondary endpoints measured fasting plasma glucose and HbA1c at one-year follow-up. Ninety-seven patients (83%) completed the one-year follow-up clinic visit. The fasting plasma glucose and HbA1c levels significantly decreased after RYGB. At the six and twelve months postoperative mark, the levels were still low but had seemed to plateau. At baseline, fasting plasma glucose levels were 164, at six months they were 104 and at twelve months they were 101 (Table 3, Appendix D). The two-sided p-value was statistically significant at p<.0001. For HbA1c, at baseline it was 7.7%, at six months it was 6.1% and at twelve months it was 6.0%, the two-sided p-value was statistically significant at p<.0001 (Table 3, Appendix D). Complete resolution of type II diabetes was achieved in seventy-two patients (74%). All of the remaining twenty-five patients decreased the daily medication requirements (partial resolution). The cohort of patients was then divided into two groups: complete type II diabetes resolution, n=72 and partial type II diabetes resolution, n=25. Preoperative waist circumference was a significant predictor for resolution of type II diabetes. The complete response group had a significantly smaller waist circumference than the partial response group. Type of medical treatment was also a significant predictor of successful outcome, with patients treated only with oral hypoglycemic medications achieving a higher percentage of complete response than patients treated with insulin. Complete resolution of type
II diabetes was also associated with a lower preoperative level of HbA1c. The preoperative HbA1c in the complete resolution group was 7.5% +/- 1.3, whereas, the partial resolution group had a HbA1c of 8.6 +/- 1.7, and the two-sided p-value was .001.

Peterli, Wolnerhanssen, Peters and Devaux (2009), studied the improvement in glucose metabolism following the laparoscopic roux-en-y gastric bypass (RYGB) or the laparoscopic sleeve gastrectomy (LSG) surgery. This study was a randomized, prospective, parallel group trial that used a computer-generated program to randomize twenty-seven patients to either LRYGB or LSG. After randomization, thirteen patients underwent LRYGB and fourteen LSG. None of the patients in the LRYGB had type II diabetes, whereas three patients in the LSG group did. With the exception of one patient in the LSG group, all other patients in both groups had an abnormal HOMA-ir index >3.8, indicating insulin resistance. In the LRYGB group, baseline levels for glucose (mmol/L), insulin (U/mL) and the HOMA-ir were 5.7, 28.3 and 9.1 (Table 4, Appendix E). In the LSG group, baseline levels for glucose, insulin and the HOMA-ir were 6.3, 37.0 and 9.1 (Table 5, Appendix F). At one week postoperatively the patients who underwent LRYGB, the glucose, insulin and HOMA-ir levels were 5.6, 21.6 and 6.1 and at three months postoperatively, these same levels were 5.1, 14.9 and 3.4 (Table 4, Appendix E). At one week post-op the patients who underwent LSG, the glucose, insulin and HOMA-ir levels were 5.5, 23.9 and 6.0 and at the three months postoperatively, these same levels were 5.4, 24.2 and 4.0 (Table 5, Appendix F). The p-value between the two groups using the HOMA-ir was
statistically significant at the one week mark, \( p = 0.018 \), and three month mark, \( p < 0.0001 \). Postoperatively, fasting insulin concentrations were reduced in both groups. An improvement in the HOMA-ir was seen as early as one week postoperatively in both groups, and most subjects were found to be as insulin sensitive as lean normal weight subjects three months after the operation. Two of the three patients with manifest diabetes were euglycemic without medication, and one with long standing type 2 diabetes showed significant improvement but was still insulin dependent.

**DISCUSSION**

The primary goal of this review was to examine the effectiveness of gastric bypass surgery with regards to improvement of glycemic control in type II diabetes. The use of gastric bypass surgery as a treatment option remains a difficult area to research due to the lack of completed studies directly comparing the results of gastric bypass with no surgical intervention. A single study in this trial only used twenty-seven patients as part of the subject group, however, it was designed as a randomized control trial and the outcome was sufficient to be relevant to the review. The other studies clearly reported the flow of the participants through the trials and reported a large enough sample size. The trials all had a sufficient follow-up period ranging from three months to two years.

According to Dixon et al. (2008), the group that underwent surgery displayed a five times higher remission rate and four times greater reduction in HbA1c values than the conventionally treated group. In addition to superior glycemic control, this study also confirmed that there were significant
improvements in insulin sensitivity as well as a reduction in the use of oral
diabetic medications in the surgical group. This randomized trial demonstrated
that weight loss associated with gastric banding resulted in diabetes remission in
the majority of obese participants recently diagnosed (<2 years), and was
associated with greater improvement in the use of related medications. This
study has provided a high level of evidence in the form of a randomized
controlled trial in supporting the consideration of bariatric surgery as a treatment
option for type II diabetes.

In the study conducted by Torquati et al. (2005), the results clearly
demonstrated that RYGB achieves better glycemic control than the most
effective medical treatments. RYGB had a significantly greater decrease in
HbA1c and a decreased requirement for diabetes medications than a low-calorie
diet. Twelve months after RYGB surgery, a mean HbA1c decrease of 1.7%, and
74% of patients were not taking any anti-diabetic medications in comparison to
the patients treated with a low calorie diet who only experienced a 0.6%
reduction in HbA1c and only 26% of patients were taking reduced doses of
diabetes medications; none were able to discontinue anti-diabetic medications.
This study clearly showed that the RYGB is highly effective in achieving excellent
glycemic control in patients with type II diabetes, although the low-grade score
renders further research necessary.

According to Peterli et al. (2009), both the LRYGB and LSG procedures
were associated with an amelioration in glycemic control which was seen as
early as eight to ten days after either of the two procedures, as measured by both
the glucose and insulin plasma levels. The HOMA-ir index was significantly improved in most subjects, with the majority of patients found to be as insulin sensitive as lean, normal-weight subjects three months after the operation. Although this study was conducted as a randomized control trial, only three diabetic patients were included in the LSG surgical group. However, this does not appear to have skewed the data, as the LRYGB was expected to show better glycemic control in comparison to the LSG. Surprisingly, the LSG patients showed a similar improvement in glucose metabolism despite having all three diabetic patients, two of whom had a complete resolution of their diabetes within three months of the operation. This further strengthens the picture that gastric bypass surgery as a whole rapidly improves glycemic control in type II diabetic patients, although GRADE gives this test a moderate score distinguishing it from Dixon et al. (2008).

The outcomes reviewed for this systematic review were fasting plasma glucose (FPG), HbA1C, insulin levels and diabetes remission. All were of moderate quality after being reviewed by the GRADE system, giving the evidence a grade of moderate overall (Appendix A). A moderate grade means that further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate overall. The randomized control trial conducted by Peterli et al. was deducted one point for only having twenty-seven participants in the study. With such a small sample size, the results could be considered imprecise, thus having a wide confidence interval around the estimate of effect for FPG and HbA1C. The remaining outcomes of diabetes
remission and insulin levels were neither up or downgraded in both of the randomized control trials as well as the cohort study. Both of the randomized control trials were given a starting grade of high, and the cohort due to being an observational study, was given a starting grade of low.

CONCLUSION

There is now considerable evidence that operations previously performed as weight loss procedures may have the added benefit of improving glycemic control and inducing long term diabetes remission. As demonstrated in this systematic review, gastric bypass surgeries be they RYGB, LSG or LAGB, should be performed for whom pharmacotherapy has proven ineffective. The concept of complete and long-term diabetes remission was demonstrated in the normalization of blood glucose levels, insulin, HbA1c and the discontinuation of diabetes medications in a large number of patients. This systematic review supports the new concept of ‘diabetes surgery’, one in which a surgical intervention is intentionally used to treat diabetes. Further research is likely to support this conclusion.
REFERENCES


### APPENDIX A

#### GRADE Table

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Outcome</th>
<th>Quantity and type of evidence</th>
<th>Findings</th>
<th>Decrease GRADE</th>
<th>Increase GRADE</th>
<th>Grade of Evidence for Outcome</th>
<th>Overall GRADE of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastric Bypass Surgery vs. No Surgery</td>
<td>FPG</td>
<td>2 RCT 1 Cohort</td>
<td>↓ FPG</td>
<td>High</td>
<td>Low</td>
<td>0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>HbA1c</td>
<td>1 Cohort 2 RCT</td>
<td>↓ HbA1C</td>
<td>Low</td>
<td>High</td>
<td>0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Remission of T2DM</td>
<td>1 RCT 1 Cohort</td>
<td>Complete Remission</td>
<td>High</td>
<td>Low</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Insulin Needs</td>
<td>1 Cohort 1 RCT</td>
<td>↓ Insulin</td>
<td>Low</td>
<td>High</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

### APPENDIX B
Table 1. Baseline Characteristics of Participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Surgery (n=30)</th>
<th>Conventional Therapy (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c mean (SD), %</td>
<td>7.8 (1.2)</td>
<td>7.6 (1.4)</td>
</tr>
<tr>
<td>Plasma glucose mean (SD), mg/dL</td>
<td>156.7 (38.5)</td>
<td>158.0 (48.7)</td>
</tr>
<tr>
<td>Plasma insulin median (IQR), uIU/mL</td>
<td>19.7 (16.5-27.5)</td>
<td>18.7 (13.7-30.7)</td>
</tr>
</tbody>
</table>
### Table 2. Primary and Secondary Outcomes at 2 years

<table>
<thead>
<tr>
<th>Variable</th>
<th>Surgery (n=30)</th>
<th>Conventional Therapy (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remission of Diabetes No. (%)</td>
<td>22 (73)</td>
<td>4 (13)</td>
</tr>
<tr>
<td>HbA1c %</td>
<td>6.0 (0.82)</td>
<td>7.21 (1.39)</td>
</tr>
<tr>
<td>Plasma glucose, mg/dL</td>
<td>105.6 (30.3)</td>
<td>139.6 (38.1)</td>
</tr>
<tr>
<td>Plasma insulin, µIU/mL</td>
<td>9.8 (4.7)</td>
<td>24.1 (13.6)</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>1.90 (0.73)</td>
<td>3.50 (0.97)</td>
</tr>
</tbody>
</table>

### APPENDIX D

#### Table 3. Effect of Gastric Bypass on the glucose metabolism

<table>
<thead>
<tr>
<th>Fasting plasma glucose (mg/dL)</th>
<th>HbA1C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative</th>
<th>1 week</th>
<th>3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>164 +/- 55</td>
<td>7.7 +/- 1.5</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>104 +/- 43</td>
<td>6.1 +/- 1.3</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>101 +/- 38</td>
<td>6.0 +/- 1.1</td>
<td></td>
</tr>
<tr>
<td>Two-sided p-value</td>
<td>.0001</td>
<td>.0001</td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX E

Table 4. HOMA Index, Glucose and Fasting Insulin Before, and 1 week and 3 months postoperatively after LRYGB: Mean +/- SD and (Range)
### APPENDIX F

#### Table 5. HOMA index, Glucose and Fasting Insulin Before, and 1 weeks and 3 months postoperatively after LSG: Mean +/- SD and (Range)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative</th>
<th>1 week</th>
<th>3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOMA Index</td>
<td>9.1 +/- 1.7</td>
<td>6.0 +/- 1.4</td>
<td>4.0 +/- 0.6</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>5.7 +/- 0.8</td>
<td>5.6 +/- 0.7</td>
<td>5.1 +/- 0.5</td>
</tr>
<tr>
<td>Insulin</td>
<td>28.3 +/- 13.3</td>
<td>21.6 +/- 5.2</td>
<td>14.9 +/- 3.7</td>
</tr>
<tr>
<td></td>
<td>6.3 +/- 1.8</td>
<td>5.5 +/- 1.9</td>
<td>5.4 +/- 1.0</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulin</td>
<td>37.0 +/- 26.1</td>
<td>23.9 +/- 15.7</td>
<td>24.2 +/- 17.3</td>
</tr>
</tbody>
</table>