Impact of Bariatric Surgery on Type II Diabetes

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1 Introduction

Type II diabetes mellitus is a major co-morbidity of obesity that predisposes patients to significant end-organ damage. It has become a major health concern in regards to its equally significant rising prevalence levels with rising body mass index worldwide. 80 per cent of people with type II diabetes are overweight or obese at the time of diagnosis.

The underlying patho-physiology is multi-factorial and complex. Obesity is associated with a chronic low-grade inflammatory state which results in a complex metabolic dysfunction called metabolic syndrome. Excessive adipose tissue causes an imbalance of regulatory hormones resulting in peripheral insulin resistance and relative insulin insufficiency leading to type II or non-insulin dependent diabetes mellitus (NIDDM).

The management of type II diabetes focuses on lifestyle interventions, lowering other cardiovascular risk factors and weight loss. A proper diet and exercise are the foundations of diabetic care followed by pharmacological treatment. Weight loss surgery or bariatric surgery has emerged as an effective treatment option for obese diabetic patients. Studies report a significantly higher rate of type II diabetes remission or improvement and decrease in long-term mortality following bariatric surgery compared to non surgical treatment. The sustained weight loss, caloric restriction, improvement in insulin resistance and beta cell function, and correction of gastrointestinal hormone imbalance cumulatively result in improved glucose homeostasis after bariatric surgery.

In this chapter we address the key points of occurrence, patho-physiology of type-II diabetes in morbid obesity and treatment options focusing mainly on bariatric surgery and its mechanism of action and outcomes in obese diabetic individuals. A brief analysis of the economic impact of bariatric surgery in light of its clinical effectiveness and cost effectiveness is also discussed at the end of the chapter.

The occurrence of obesity and type-II diabetes are both recognised as a global epidemic and their reciprocal prevalence indicates a strong relationship between them. The prevalence of obesity in the world has been steadily rising. In a systemic review in 2008, 1.46 billion adults worldwide were estimated to be overweight and of those 502 million were obese (Finucane et al., 2011). Obesity is associated with a multitude of co-morbidities and hence an attributable mortality is due to these related disorders (Pi-Sunyer, 1993). The likelihood of developing type II diabetes rises steeply with increasing body fatness. It is a major co morbidity of obesity that predisposes patients to significant end-organ damage. It has become a major health concern in regards to its equally significant rising prevalence levels with rising body mass index worldwide (Shamseddeen et al., 2011). According to the International Diabetes Federation (IDF), worldwide 80 per cent of people with type II diabetes are overweight or obese at the time of diagnosis.

There are various treatment modalities for type II diabetes including life style changes, diet modification and oral hypoglycaemic agents. Surgery has not had much of a role to play in the treatment of diabetes though historically subtotal-gastrectomy has been reported to cause improvement or remission of diabetes more than 50 years ago (Friedmann et al., 1955). Recently bariatric surgery has become a popular weight loss intervention which also effectively controls diabetes associated with obesity. It has proven to be a more effective measure than other standard treatments of type II diabetes (Dixon et al., 2008). Its mechanism of action is multi-factorial and complex with weight-loss playing a pivotal role.
2 Patho-physiology of Type-II Diabetes in Obesity

Occurrence of type-II diabetes in obese individuals has a complex and multifactorial patho-physiology (Figure 1). The major factor in the pathogenesis of type-II diabetes is peripheral insulin resistance which is defined as an *inadequate response by insulin-sensitive tissues to normal circulating levels of insulin* (Reaven G.M, 1988; Kalupahana et al., 2011; Romeo et al., 2012). There is a direct association of increased body mass index to development of type-II diabetes. However, there are many coexisting conditions, such as hypertension, dyslipidaemia, or insulin resistance that may affect this relationship (Sanada et al., 2012).

![Pathophysiology of obesity and development of type-II diabetes](image)

**Figure1:** Shows the summary of pathophysiology of type II diabetes in morbid obesity.

Obesity particularly visceral obesity induces insulin resistance in various tissues predominantly skeletal muscles, liver, and adipose tissue (Yang et al., 2005). Several models have been proposed to explain the strong association of obesity and insulin resistance (Kalupahana et al., 2011; Belkina and Denis, 2010).

Adipose tissue is an active endocrine organ that secretes Non-Esterified Fatty Acids (NEFAs), glycerol and various humoral factors called adipokines (Scherer PE, 2006; Shoelson SE et al., 2006; Wellen KE et al., 2005). The adipokines are grouped as immune response mediators and inhibitors. Several prospective studies have shown a relationship between adipokines and the risk of developing type II diabetes (Pradham AD et al., 2001; Lindsay RS et al., 2002). There is a dysregulated production of pro-inflammatory and anti-inflammatory adipokines in the obese adipose tissues resulting in a chronic inflammatory state (Romeo et al., 2012). The exact mechanism that triggers this inflammatory state is not known. It has been proposed that obesity results in hyperadiposity and accumulation of large amounts of
fats and triglycerides in the adipose cells (Kalupahana et al., 2011). Excessive storage of fats may not be paralleled with an equal increase in adipose tissue vascularity leading to cellular hypoxia which causes stress of endoplasmic reticulum and cell injury. This process elicits activation of innate immune processes in the adipose tissue (Kalupahana et al., 2011). Recent studies have shown that the cells of the innate immune system, particularly macrophages, are crucially involved in adipose tissue inflammation and systemic metabolic abnormalities (Niashimura et al., 2009). Macrophages are key mediators of obesity-induced insulin resistance, with a progressive infiltration of macrophages into excessive adipose tissue. These adipose tissue macrophages are referred to as classically activated macrophages. They release cytokines such as IL-1β, IL-6 and TNFα creating a pro-inflammatory environment in the adipose tissues as well as a low grade systemic inflammatory state (Harford et al., 2001). Adipocytes also secrete substances including resistin that directly contribute to peripheral insulin resistance (Kalupahana et al., 2011). Non-esterified Fatty Acids (NEFAs) are also key modulators of insulin resistance. Raised levels of NEFAs are found in obesity and type II diabetes, therefore are associated to insulin resistance observed in obesity and type II diabetes (Reaven GM et al., 1988; Boden G, 1997)

The visceral accumulation of lipids due to obesity also causes disruption in adipogenesis by disturbing the energy balance (Kalupahana et al., 2011). Increased lipid accumulation in the liver and skeletal muscle is associated with increased saturated fatty acid flux, which leads to excessive accumulation of fatty acid intermediates. These fatty acid intermediates along with the inflammatory cytokines interfere with the insulin receptors on the cells and disrupt the insulin uptake cascade which eventually leads to insulin resistance (Kalupahana et al., 2011; Donath MY & Shoelson SE, 2011).

Insulin resistance leads to impairment in insulin-mediated suppression of hepatic glucose production, skeletal muscle glucose disposal, and inhibition of lipolysis, leading to relative hyperglycaemia and increased plasma levels of free fatty acids (Kalupahana et al., 2011).

As a compensatory response to the relative hyperglycaemia, pancreatic β-cells start secreting more insulin. This hypersecretion of insulin in turn increases skeletal muscle glucose uptake and inhibits hepatic glucose production to maintain normoglycaemia. Long-term insulin resistance and hypersecretion of insulin eventually leads to pancreatic β-cell failure. Chronic exposure of the pancreas to elevated free fatty acid concentrations also has deleterious effect on the beta cells (Bollheimer LC et al., 1998; Paolisso G et al., 1995). These events result initially in pre-diabetes and glucose intolerance and later progress to hyperglycaemia and type II diabetes (Kahn SE et al., 2006).

3 Bariatric Surgery: An Effective Treatment Option for Type-II Diabetes in Morbid Obesity

Type-II diabetes is a progressive disorder with diverse medical complications. Early and effective management of this disorder is the key to slow progression and development of associated cardiovascular risks and end organ damage (Caroli et al., 2008). Management of type II diabetes focuses mainly on lifestyle interventions, lowering other cardiovascular risk factors and weight loss. A proper diet and exercise are the foundations of diabetic care followed by pharmacological treatment (Knowler et al., 2002; Keller, 2006). A number of drugs are being used globally and are found to be effective to treat type-II diabetes but not one therapeutic intervention, or even a combination of two or more interventions have proven to control this heterogeneous disorder (Dixon et al., 2012; Liebl et al., 2002). Traditionally used drugs such
as sulphonylureas and metformin, and newer ones such as the glitazones, dipeptidyl peptidase 4 inhibitors and glucagon-like peptide 1 agonists, all have a role but do not provide adequate control in many cases (Dixon et al., 2012; Nathan et al., 2009).

The global rising trends of type-II diabetes are parallel to that of obesity and more than 60% of patients with type-II diabetes are obese (Kramer et al., 2010). Prevention and treatment of obesity and type-II diabetes combined, often called diabesity, has become a health priority (Astrup et al., 2000; Dixon et al., 2012). There is a significant positive effect of weight loss alone on glycaemic control and improvement in cardiac risk factors associated with type-II diabetes. It has been reported that a 7 kg weight loss, combined with 150 minutes a week of physical activity, reduces the incidence of developing type II diabetes by 58% in overweight individuals with impaired glucose tolerance (Knowler et al., 2002). Additionally a 10 kg reduction in weight in a type-II diabetic patient improves fasting blood glucose up to 50% with a reduction in diabetes related death up to 30% (Pagotto et al., 2008; Colquitt et al., 2005). Thus weight loss is being considered as an attractive, but challenging, therapeutic option to treat the entire type-II diabetes disorder (Dixon et al., 2012).

Weight loss strategies include dietary changes, lifestyle modifications, pharmacological treatment and weight loss surgery or bariatric surgery (Rao G, 2010; Shepherd A. 2010). Behavioural and pharmacological treatments of obesity can result in short-term weight loss so the only approach to achieve a significant and sustainable weight reduction is bariatric surgery (McTigue et al., 2003; Pories et al., 1995; Dixon et al., 2012).

Bariatric surgical procedures are “a group of procedures that are aimed at reducing caloric intake and absorption by modifying the anatomy of the gastrointestinal tract resulting in sustainable long-term weight loss that leads to improvement in type II diabetes and other obesity related co morbidities especially cardiovascular disease, quality of life and mortality” (Dixon et al., 2012; Sjöström et al., 2002; Buchwald et al., 2004; Sjöström et al., 2007).

The criteria for eligibility for bariatric surgery according to the National Institute of Health (NIH) guidelines are:

• Patients who are 18 to 55 years old and fit for surgery
• BMI >40 or 35-39 with co morbidities that can be improved with surgery
• Agreeable to lifelong follow-up
• Failed conservative treatment

The history of bariatric surgery links back to 1954 when the first bariatric procedure, jejunoileal bypass was performed by Kerman (Kremen et al., 1952). Improvement or remission of diabetes after gastrectomy was initially reported more than 50 years ago (Friedmen et al., 1955). Pories and colleagues described sustained changes in glycaemic control for up to 14 years after gastric bypass surgery in morbidly obese patients with diabetes in 1995 (Poires et al., 2008). Bariatric surgery was included as a treatment option for obese diabetics by American Diabetes Association in 2009 and by International Diabetes Federation in 2011.

A summary of recent literature reviews, about effectiveness of bariatric surgery as a treatment modality for type II diabetes in obesity, is given in Table 1.
<table>
<thead>
<tr>
<th>Author/year</th>
<th>Type of study</th>
<th>Treatment Modalities Assessed</th>
<th>Results/Conclusion</th>
<th>Future Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bradley D. et al. 2012</td>
<td>Review article</td>
<td>All types of BS* and CM*</td>
<td>BS* is more effective than CM*</td>
<td>To study involved mechanisms</td>
</tr>
<tr>
<td>Davies A.R et al. 2012</td>
<td>Review article</td>
<td>All types of BS* and CM*</td>
<td>BS* is an effective treatment compared with CM*</td>
<td>Larger RCTs required</td>
</tr>
<tr>
<td>Flatt PR. et al. 2012</td>
<td>Review article</td>
<td>RYGB vs. Restrictive procedures</td>
<td>RYGB is more effective</td>
<td>N/A</td>
</tr>
<tr>
<td>Lautz D. et al. 2011</td>
<td>Review article</td>
<td>All types of BS* vs. CM*</td>
<td>BS* is effective but no clear statement given</td>
<td>N/A</td>
</tr>
<tr>
<td>Anvari M. 2011</td>
<td>Review article</td>
<td>GBP*, SG*, AGB*, CM*</td>
<td>BS* is an effective treatment</td>
<td>Reconsider guidelines to provide BS* to more pts.*</td>
</tr>
<tr>
<td>Rao RS. et al. 2011</td>
<td>Review article</td>
<td>All BS* Long term study</td>
<td>RYGB* and BPD* is more effective than LAGB* Long term effectiveness of SG* is not known BS* also effective in adolescent and BMI&lt;35</td>
<td>N/A</td>
</tr>
<tr>
<td>Dixon JB. et al. 2011</td>
<td>Review article</td>
<td>LAGB*</td>
<td>LAGB* is an effective treatment option</td>
<td>Long term studies required</td>
</tr>
<tr>
<td>Gill RS. et al. 2010</td>
<td>Review article</td>
<td>LSG* Total pts* involved-673</td>
<td>LSG* is an effective treatment (66.1% resolution)</td>
<td>Larger RCT required</td>
</tr>
<tr>
<td>Dixon JB. et al. 2009</td>
<td>Review article</td>
<td>All BS* and CM*</td>
<td>BS* is associated with remission of DM in 50-89%</td>
<td>N/A</td>
</tr>
<tr>
<td>Buchwald H et al. 2009</td>
<td>Meta-analysis</td>
<td>All types of BS* Total pts* involved-1,35,246</td>
<td>BS* is an effective treatment (78.1% resolution), especially mal-absorptive procedures</td>
<td>RCTs comparing BS* and CM*</td>
</tr>
</tbody>
</table>

Table 1: Table summarising the recent literature reviews about bariatric surgery as a treatment option for type II diabetes in obese patients *(BS= Bariatric surgeries, CM=Conservative management, RYGB =Roux en Y gastric bypass, BPD= Bilio Pancreatic Diversion, LAGB= Laparoscopic Adjustable Gastric Banding, AGB= Adjustable Gastric Banding, SG=Sleeve Gastrectomy, LSG=Laparoscopic Sleeve Gastrectomy Pts.=Patients, RCT= Randomised Controlled Trials).

4 Types of Bariatric Surgery

Bariatric procedures are classified as either restrictive, mal-absorptive or a combination of both (Abell TL & Minocha A, 2006; Shabbir et al., 2009; Elder KA & Wolfe BM, 2007; De Marie, 2007; Dixon et al., 2011; Bult et al., 2008).

4.1 Restrictive Procedures

These procedures act to reduce oral intake by limiting gastric volume, produces early satiety, and leave the alimentary canal in continuity, minimizing the risks of metabolic complications (Stanczyk et al., 2007; Shabbir et al., 2009). Commonly performed restrictive procedures are discussed below.
4.1.1 Adjustable Gastric Band

The restriction of the stomach can also be created using a silicone band, which can be adjusted by addition or removal of saline through a port placed just under the skin (Figure 2). This operation can be performed laparoscopically, and is commonly referred to as a "laparoscopic adjustable gastric banding LAGB". Weight loss is predominantly due to the restriction of nutrient intake that is created by the small gastric pouch (Shikora et al., 2007). A series from O’Brien and Dixon et al. (2005) had a 50% EWL up to 6 years follow-up after LAGB. It is considered one of the safest procedures performed today with a mortality rate of 0.05% (Freitas & Sweeney, 2010).

![Figure 2:](image)

**Figure 2:** It demonstrates the mechanism and placement of an adjustable gastric band.

4.1.2 Vertical Sleeve Gastrectomy

In this procedure the capacity of stomach is reduced to about 25% of its original size by surgical removal of part of stomach along the greater curvature. The rest of stomach remains in the shape of a sleeve or tube (Figure 3). This procedure is performed laparoscopically and is irreversible. It is a good and safe option for super obese patients (BMI >55 kg/m²) as a method for initial weight loss (Shabbir et al., 2009). It can later be combined with the duodeno-ileostomy to construct the intestinal bypass component of the bilio-pancreatic bypass procedure (Elder KA & Wolfe BM, 2007). With this procedure patients are expected to lose 30-50% of their excess body weight in 6-12 months to more than 60% in two years time period (Nocca et al., 2008).

4.2 Mal-absorptive procedures

These procedures act by bypassing varying portions of the small intestine where nutrient absorption occurs leading to mal-absorption (Shabbir et al. 2009). Commonly performed mal-absorptive procedures are discussed below.

4.2.1 Bilio-pancreatic diversion BPD / duodenal switch (DS)

In bilio-pancreatic diversion part of the stomach is resected, creating a smaller stomach. The distal part of the small intestine is then connected to the pouch, bypassing the duodenum and jejunum (figure 4 left).
Figure 3: The Figure demonstrates the portion of stomach along the greater curvature that is excised to reduce the gastric space to up to 25% of its original size.

Figure 4: BPD (left) = an approximate 50%–80% gastrectomy is done and then the gastric remnant is anastamosed to distal part of ileum bypassing the duodenum and jejunum. BPD with DS (right) = in this procedure a gastric sleeve is created by vertical resection of the greater curvature of the stomach creating a long tubular stomach along the lesser curvature. A duodenostomy ileostomy is done either end-to-end or end-to-side fashion, thereby preserving the pylorus.
To perform a bilio-pancreatic diversion with duodenal switch, following a sleeve gastrectomy, the duodenum is mobilised and transected. Ileum is divided and the distal ileal loop is anastamosed end to end to the gastro-duodenal stump creating the alimentary loop (Figure 4 right) (Shabbir et al., 2009). Excess weight loss for BPD and BPD with DS at 8 years is 77% and 70%, respectively (Scopinaro et al., 1996; Hess et al., 1998).

4.2.1 Bilio-pancreatic Diversion BPD / Duodenal Switch (DS)

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Bilio-pancreatic diversion alone has a greater risk for malnutrition in patients. A combination of BPD with duodenal switch DS decreases risk of post-operative malnutrition compared to BPD alone (Shabbir et al., 2009). It is an option for morbidly obese patients resulting in rapid weight loss (Tonstad et al., 2007).

4.2.2 Jejunoileal Bypass (JIB)

It was a surgical weight loss procedure performed from the 1950s through the 1970s in which all but 30 cm (12") to 45 cm (18") of the small bowel was detached and set to the side. JIB is the classic example of a mal-absorptive weight loss procedure (Payne JH & DeWind LT, 1969). There is a long list of mal-absorptive complications owing to this procedure because of which it is no longer preferred (Griffen et al., 1983).

4.3 Mal-absorptive Combined with Restrictive Procedures

Gastric bypass procedures (GBP) are any of a group of similar operations that first divides the stomach into a small upper pouch and a much larger lower "remnant" pouch and then re-arranges the small intestine to allow both pouches to stay connected to it. Gastric bypass acts by both mal-absorption and restriction of food to induce sustainable weight loss (Maggard et al., 2005). The gastric bypass, in its various forms, accounts for a large majority of the bariatric surgical procedures performed. It is estimated that 200,000 of such operations were performed in the United States in 2008 (Ainsworth C, 2009).

4.3.1 Gastric Bypass, Roux En-Y (Proximal or Distal)

This type of gastric bypass is popular worldwide and can be done laparoscopically (Maggard et al., 2005; Shabbir et al., 2009). The procedure involves creating a 30 ml proximal gastric pouch using a linear cutting stapler leaving the distal gastric remnant separate from the pouch. Then 50 to 100 cm away from the ligament of Trietz, the jejunum is divided and this creates a proximal bilio-pancreatic limb. Jejunum is distally anastomosed to the bilio-pancreatic limb, thus forming a distal common channel and proximal
alimentary limb called the “Roux limb”. The proximal end of the Roux limb is anastomosed to the gastric pouch creating a tight gastro-jejunostomy, a Y-shaped intestinal anatomy (Figure 5) (Shabbir et al. 2009; Elder KA & Wolfe BM, 2007). An excess weight loss of more than 40% can be achieved with gastric bypass in two years time (Shabbir et al., 2009). Another study reported an average excess weight loss of 56.3% and 48.3% at 4 and 8 years, respectively (Ti TK, 2004).

Figure 5: It demonstrates Roux-en-Y gastric bypass which is performed by creating a proximal gastric pouch and jejunum is resected forming a bilio-pancreatic limb. Jejunum 150 cm distal from the divided end is anastomosed to the bilio-pancreatic limb, thus forming a distal common channel and proximal alimentary limb called the “Roux limb”. The proximal end of the Roux limb is anastomosed to the gastric pouch creating a tight gastro-jejunostomy a Y-shaped intestinal anatomy.

5 Mechanism of Action of Bariatric Surgery

Bariatric procedures lead to sustained weight loss due to restriction of calorie intake and the anatomical and functional changes in the gastrointestinal tract after surgery (Dixon et al., 2012). The sustained weight loss after bariatric surgery has been reported to improve glycaemic control in obese diabetics especially in morbidly obese patients. Studies have also reported remission of type-II diabetes after surgery (Dixon et al., 2008; Buchwald et al., 2009; Pournaras et al., 2010; Sjöström et al., 2007).

Bariatric surgery is an excellent model to study integrated physiology of energy balance and weight-related metabolic disorders, including type II diabetes. Initial rapid weight loss after surgery owes to the decrease in caloric intake and changes in eating (Colles et al., 2008). Maintenance of weight loss is probably more important than initial weight loss for long-term glycaemic control. Glycaemic control deteriorates in bariatric surgery patients who are unable to maintain weight loss (Chikunguwo et al., 2010).

The mechanism by which different bariatric operations improve diabetes is complex and incompletely understood. Bariatric surgery characteristically attenuates appetite, changes food preferences, induces rapid improvement of hyperglycaemia, reduces hepatic insulin resistance, and improves insulin
secretion (Pournaras et al., 2010; Nannipieri et al., 2011; Le Roux et al., 2011; Dixon et al., 2012). Diabetes remission results from the joint improvement of insulin resistance and β-cell dysfunction.

5.1 Energy Balance and Altered Insulin Sensitivity

Weight loss after surgery corresponds to the depletion of subcutaneous as well as visceral fat. This decrease in adiposity results in reversal of the chronic inflammatory state and increases adiponectin secretion that improves insulin sensitivity in the adipose tissues (Gumbs et al., 2005). Presence of inflammatory mediators which is a characteristic of obese adipose tissue and interferes with insulin cascade is also decreased after bariatric surgery. Eventually a decrease in adiposity directly influences insulin sensitivity in the liver and skeletal muscles. There is also reversal of the disturbances in glucose metabolism and lipolysis, possibly due to changes in endocrine activity of the adipose tissue and the caloric intake restriction. Decreased food intake creates an energy balance in the body and also helps to regulate glucose and lipid metabolism (Dixon et al., 2012).

An analysis of published data reporting improvement of insulin sensitivity in morbidly obese diabetic patients after bariatric surgery concluded that bariatric procedures, predominantly mal-absorptive procedures all result in long-term improved insulin sensitivity paralleling weight loss (Ferrannini et al., 1997; Dixon et al., 2012). The European Group for the Study of Insulin Resistance (EGIR) cohort (Ferrannini et al., 1997) and the study by Muscelli et al., 2005 both reported that a 30% reduction in BMI (from 46 kg/m²) predicts a 50% increase in insulin sensitivity after bariatric surgery.

5.2 Changes in β-cell Function and Effect of Gastrointestinal Hormones

With purely or mostly restrictive procedures, β-cell function shows progressive improvement over time with ongoing weight loss. This is partially due to the released pressure on β-cells after surgery to secrete more insulin owing to improved insulin sensitivity (Weir et al., 2009; Dixon et al., 2012; Ferrannini et al., 2009). A change in the hormones secreted by gastrointestinal tract has also been reported after bariatric procedures (Dixon et al., 2012). These changes alter the food digestion process and are thought to effect β-cell function. Ghrelin, a hormone secreted by the gastric fundus is believed to interfere with insulin resistance. Glucagon-like peptide-1 (GLP-1) secreted in the intestine potentiates insulin release in a glucose-dependent manner and its high levels after bariatric surgery is thought to participate in the improved β-cell function (Dixon et al., 2012).

Augmented glucose tolerance is noted after bariatric procedures that involve duodenal exclusion (RYGB and BPD). It is hypothesized that contact of nutrients to duodenal mucosa produces hormonal and neural signals that has an impact on glucose tolerance and insulin secretion. Thus, omitting a part of the duodenum is thought to improve glucose metabolism (Ferzli et al., 2009; Dixon et al., 2012). BPD also leads to lipid mal-absorption as it depletes intra-myocellular lipids present in bile and returns insulin sensitivity to normal levels in the long term (Ferrannini et al., 2009). The purely restrictive procedures help in improved glucose and lipid metabolism by caloric restriction alone. Gastric bypass which is a combination of mal-absorptive and restrictive procedure causes caloric restriction, decreased ghrelin production, mal-absorptive effects by duodenal exclusion eventually resulting in improved insulin sensitivity and a better glycaemic control (Dixon et al., 2012).

Research on new anatomical arrangements and augmentation of conventional bariatric procedures is being done to specifically treat type-II diabetes. These arrangements include removal of the gastric fundus to reduce ghrelin secretion, bypass of the duodenum and upper jejunum to provide duodenal ex-
clusion and deliver chyme prematurely to the distal jejunum (perhaps activating foregut and hindgut mechanisms), and ileal interposition to engage hindgut mechanisms. These procedures have been used alone and in combination (Dixon et al., 2012).

**Mechanism of action of commonly performed bariatric procedures on glycaemic control in morbidly obese type-II diabetic patients**

- **RYGB**
  - Duodenal bypass
  - Malabsorption
  - Increased GLP-1
  - Decreased ghrelin
  - Increased insulin secretion
  - Decreased glycaemic load
  - Decreased hepatic glucose production
  - Decreased free fatty acids
  - Decreased liver fat
  - Decreased peripheral adipose tissue
  - Increased adiponectin, decreased inflammatory mediators
  - Increased insulin sensitivity
  - Improved glycaemic control

- **LAGB**
  - Malabsorption
  - Decreased caloric intake

**Figure 6**: It summarises the mechanism of action of bariatric surgery in glycaemic control of type II diabetes in morbid obesity.

## 6 Outcomes of Bariatric Surgery

The overall outcome of bariatric surgery can be assessed by measuring its excess weight loss, improvement of co-morbid conditions, complications and a decrease in the mortality rate (Padwal et al., 2011; Buchwald H & Williams SE, 2004; Bult et al., 2008; Maggard et al., 2005; AJ Clegg et al., 2002; Picot et al., 2009; Dixon et al., 2011).

Bariatric procedures, as in any surgery, may result in complications; however, the benefits of bariatric surgery outweigh the risks predominantly in morbidly obese diabetics. The overall complication rate of bariatric procedures is 10-20% and the occurrence may differ among procedures in clinically important ways (Maggard et al., 2005). Severe and early surgical complications are dominated by occlu-
sions and anastomotic leakages. Late complications include small bowel occlusions caused by internal hernia, adhesions or anastomotic stenosis and functional disorders such as reflux and dumping. The most common long-term complications after gastric banding include band slippage and erosion (Hamdan et al., 2011; Thereaux et al., 2010).

When compared with conventional treatment, surgery results in a significantly greater loss of weight (20kg to 30kg more weight) and 10–15kg/m² reduction in BMI which is maintained at 8-10 years post-operatively. As a consequence, there are improvements in quality of life and co-morbidities associated with the loss of weight from surgery (Padwal et al., 2011; Elder KA & Wolfe BM, 2007; AJ Clegg et al., 2002; Bult et al., 2008). In general, weight loss with mal-absorptive procedures tends to be greater than weight loss with solely restrictive procedures (De Maria, 2007).

In light of all the outcomes of different bariatric procedures the choice between adjustable gastric banding AGB and Roux-en-Y gastric bypass RYGB (the two most commonly performed procedures), appears to represent a trade-off between weight loss efficacy and risks. Adjustable gastric banding AGB is a simpler, shorter procedure that does not carry a long-term risk of mal-absorption. It also leads to a lower number of serious complications but consistently produces smaller reductions in weight and a higher requirement for overall reoperations. Sleeve gastrectomy SG appears similar to Roux-en-Y gastric bypass RYGB with respect to weight loss efficacy, although further confirmatory data are required (Padwal et al., 2011). The post-operative complications in obese patients with or without diabetes are comparable (Steele et al., 2011). All procedures result in significant improvement in medical conditions but Roux-en-Y gastric bypass RYGB may potentially exert weight-independent effects on glycaemic control (possibly due to alterations in entero-endocrine signals) and thus this technique may be particularly beneficial in patients with type II diabetes (Cummings et al., 2004).

7 Clinical and Cost Effectiveness of Bariatric Surgery in Morbidly Obese Type-II Diabetics

The clinical effectiveness of bariatric procedures in obese diabetic individuals can be measured directly by determining the improvement/resolution of clinical and laboratory manifestations of type-II diabetes after surgery. Rates of improvement and remission are directly associated with the pre operative BMI, extent of sustained weight loss after surgery, the duration of diabetes and the type of surgery performed (Dixon et al., 2012).

There are ample published data emphasizing the clinical effectiveness of bariatric procedures and its significantly high remission rates in as early as two years after the bariatric procedure. According to a literature review (Dixon et al., 2008) after 2 years, remission of diabetes was significantly more in patients who underwent bariatric surgery than in those who received standard treatment (73% vs.13%). A systematic review (Buchwald et al., 2009) has reported diabetes remission in up to 78% of diabetic obese patients and 62% remained in remission for more than 2 years after surgery. A Swedish obese subjects case-control study (Sjöström et al., 2007) reported that 36% were still in remission at 10 years after bariatric procedure. The percentage of excess bodyweight loss is about 63% for Roux-en-Y gastric bypass, 49% for laparoscopic adjustable gastric band, 46% for sleeve gastrectomy, 73% for biliopancreatic diversion with or without duodenal switch, and remission of type II diabetes occurs in 71%, 58%, 66% and 95% of patients following respective procedures. Thus biliopancreatic diversion and gastric bypass are
considered clinically effective procedures for treatment of morbidly obese diabetic individuals (Sjöström et al., 2007).

A marked improvement in fasting blood glucose (30-50%) and HbA1c (15%) as well as a decrease in utilisation of insulin and diabetic medications has also been reported post-operatively following 10 kg weight loss (Pagotto et al., 2008; Colquitt et al., 2005). Studies have shown a 70% reduction in diabetic medications use in the third post-operative year. (Segal et al., 2009; Makary et al., 2010; Thomas J Hoerger et al., 2010; Catherine L. Keating et al., 2009) In addition to these clinical benefits in obese diabetics, bariatric procedures also reduce the risk of developing diabetes and cause significant reduction in diabetes related deaths after bariatric procedures (Dixon et al., 2012).

The estimated medical expenses of diabetic populations are around 2.5 times more than the normal population. The clinical improvement in the disease and its associated reduction in direct utilisation of health services by morbidly obese diabetic patients after bariatric surgery are thus translated into significant direct economic benefits (Klein et al., 2011; Sampalis JS et al., 2004). Bariatric procedures have been shown to be cost-effective if remission is up to 2 years and cost saving if remission of diabetes is maintained up to 10 years after the procedure (Makary et al., 2010; Thomas J.Hoerger et al., 2010; Catherine L. Keating et al., 2009).

8 Conclusion

To conclude:

• Type II diabetes has become a global health problem and its prevalence is rising due to its association with rising world-wide obesity.

• Low grade chronic inflammatory state in the excessive adipose tissue, due to hypoxic injury and activation of immune system, leads to insulin resistance and disruption of glucose and lipid metabolism. Compensatory hypersecretion of insulin results in β-cells dysfunction and development of type II diabetes.

• Weight management has a vital role in the management algorithm of type-II diabetes especially in morbidly obese patients.

• Bariatric surgery has proven to be a more effective treatment of type II diabetes associated with obesity compared with conventional therapies. By achieving sustained weight loss the peripheral insulin sensitivity and β-cell dysfunction improves and remission rate of up to 78% has been reported after surgery.

• Recent studies have shown that sustained weight loss is essential to maintain the effect of bariatric surgery on type II diabetes, however long term studies are needed to establish if bariatric surgery can control type II diabetes in the long term.
References


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