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Laparoscopic revolution in bariatric surgery

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Abstract

The history of bariatric surgery is investigational. Dedicated surgeons have continuously sought for an ideal procedure to relieve morbidly obese patients from their burden of comorbid conditions, reduced life expectancy and low quality of life. The ideal procedure must have low complication risk, both in short- and long term, as well as minimal impact on daily life. The revolution of laparoscopic techniques in bariatric surgery is described in this summary. Advances in minimal invasive techniques have contributed to reduced operative time, length of stay, and complications. The development in bariatric surgery has been exceptional, resulting in a dramatic increase of the number of procedures performed world wide during the last decades. Although, a complex bariatric procedure can be performed with operative mortality no greater than cholecystectomy, specific procedure-related complications and other drawbacks must be taken into account. The evolution of laparoscopy will be the legacy of the 21st century and at present, day-care surgery and further reduction of the operative trauma is in focus. The impressive effects on comorbid conditions have prompted the adoption of minimal invasive bariatric procedures into the field of metabolic surgery.

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Key words: Laparoscopy; Bariatric surgery; Minimal invasive surgery; Gastric bypass; Duodenal switch; Gastric banding; Metabolic surgery

Core tip: Dedicated surgeons have continuously sought for an ideal procedure to relieve morbidly obese patients from their burden of comorbid conditions, reduced life expectancy and low quality of life. The ideal procedure must have low complication risk, both in short- and long-term. Advances in minimal invasive techniques have contributed to reduced operative time, length of stay, and complications. The development in bariatric surgery has been exceptional. The evolution of laparoscopy will be the legacy of the 21st century and at present, day-care surgery and further reduction of the operative trauma is in focus.

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INTRODUCTION

Obesity

At present, obesity is spreading like an epidemic. The continuous improvements in public health we have been accustomed to have come to a halt, impeded by obesity. For the first time, the life span of the next generation is predicted to be shorter than their parents. Morbidly obese patients (body mass index, BMI > 40 kg/m²) are disadvantaged in our society. Not only are they afflicted by conditions associated with morbid obesity, *i.e.*, diabetes, sleep apnoea, and cardiovascular diseases, but also forced to struggle with some of life's simple activities, like sitting comfortably in a chair or walking normal distances. The world wide dilemma of obesity requires

multiple actions, but for the already affected, bariatric surgery has become a valid option.

Surgical treatment of morbid obesity

In general, obese and especially morbidly obese patients are not well suited for any surgical treatment, but, at present, bariatric surgery is the only effective weight loss method for these patients in the long run. However, to reduce operative risks and to generate the best quality of life for patients, the chosen surgical strategy has to be very well selected and performed with high quality. The evolution of bariatric surgery has been investigational, and we owe appreciation to many great purveyors. Today, minimal invasive surgery is the first option for both surgeon and patient; however, the hard-earned fundamentals of open bariatric surgery must be preserved.

Evolution of open bariatric surgery

The surgical treatment of obesity was developed from observing patients losing weight after gastric or small bowel resections, and the first operation to treat obesity, an extensive resection of the small bowel, was performed by Henrikson in 1952. This, evidently totally irreversible operation, was followed by different types of bypasses on the small bowel, initially anastomosing the proximal jejunum to the colon, and then to the distal ileum. The jejuno-ileal bypass (JIB), leaving only the first 40 cm of the jejunum and the last 10 cm of the ileum, was developed by Kremen *et al*^[1]. In 1954, their experience with JIB was submitted as the first paper on bariatric surgery to a peer-reviewed journal. For decades, a right mid-abdominal transverse incision typically indicated previous JIB surgery in a patient, just as the other classical scars after appendectomy, cholecystectomy, and caesarean section. Despite efforts to optimize these procedures, they were abandoned because of intractable side effects, *i.e.*, diarrhoea, dehydration and hepatic cirrhosis^[2].

In the 1970s, focus was switched to the stomach in achieving reduced intake of food. Ed Mason introduced his first operation; the vertical banded gastroplasty (VGB)^[3,4], in which a small proximal gastric reservoir was created. The outlet to the remaining stomach was reinforced by a band. VGB resulted in about 50% loss of the patients overweight, unfortunately often in combination with vomiting and acid reflux. In addition, with time the gastric partitioning opened, allowing the patients to eat freely, which resulted in weight regain. Another procedure created by Mason in 1967, the gastric bypass (GBP)^[5], was adopted in the beginning of the 1980s. In GBP, the jejunum was connected to a proximal and horizontally cut stomach pouch, thus reducing intake of food by bypassing the main part of the stomach. GBP became popular in early weight loss surgery in the United States owing to limited side effects and impressive weight loss. It is, however, important to remember that, at this time, all bariatric procedures were technically demanding to perform and the perioperative risks were

high for the patients. Many personal alterations were made to overcome operative difficulties or other drawbacks, sometimes evident first several years after surgery.

The concept of malabsorption was refined by Scopinaro in 1972, developing the bileo-pancreatic diversion (BPD)^[6], consisting of a horizontal gastric resection, to reduce food intake, and a shortening of the common part of small bowel, to produce malabsorption of ingested nutrients. The BPD came to make a large and long contribution in bariatric surgery. In a similar procedure, the duodenal switch (DS), described by Hess *et al*^[7], Lagacé *et al*^[8] and Marceau *et al*^[9] in 1980s, food intake was restricted by vertical sleeve gastrectomy along the lesser curvature. After passing the pylorus, ingested food passed directly into the distal ileum, thus reducing uptake of fat. DS is known to have a lower frequency of anastomotic ulcers and dumping. Both these malabsorptive procedures result in massive and sustained weight loss, even in patients with less dietary compliance, but require life-long follow up to monitor nutritional deficiencies. In addition, some patients suffer from diarrhoea and foul gases.

For many years, weight loss surgery was unpopular with many physicians due to the side effects seen after JIB/intestinal bypasses and the high operative mortality. Three major events changed this view. First, in 1992, the National Institutes of Health (NIH) held a consensus conference, where medical experts concluded that two procedures were safe and effective in treating morbid obesity, VBG and GBP. Criteria were set to qualify for bariatric surgery, in short, being 100 pounds overweight or having a BMI above of 40 or > 35 in combination with comorbidities, with a long history of failed weight loss^[10]. This convinced an increasing number of physicians to recommend surgery for their patients suffering from obesity. Second, further acceptance was gained when Walter Pories in 1995^[11] could demonstrate the high and durable effect on diabetes mellitus, in his landmark paper, "Who Would Have Thought It? An Operation Proves to be the Most Effective Treatment for Adult-onset Diabetes Mellitus". The many following studies from the Swedish Obese Subjects (SOS) study have verified and enhanced the impressive effect on comorbid conditions. Third, the development of improved operative instruments, facilitating surgery in this difficult group of patients, reduced postoperative complications. Bariatric surgery was associated with long postoperative stay and rather high mortality, when performed with standard instruments for general surgery, requiring large incisions and long operative time. The surgical instruments routinely used today, *e.g.*, cutting linear staplers, energy devices, and other specially designed tools, were not available.

The laparoscopic revolution

In 1994, Wittgrove *et al*^[12] pioneered by performing the first laparoscopic GBP, after developing the technique in the laboratory. With a six-trocar technique they were able to create a 21-mm circular stapled gastrojejunos-

tomy to a 75-cm retrocolic retrogastric Roux limb. The anvil of the circular stapler was passed transorally, using a proprietary technique. The initial results were excellent, and the authors later reported on 500 patients who maintained 73% excess body weight loss at 54 mo^[13]. The leakage rate was low, 2.2%, and comparable to the open procedure at that time. The overall complication rate was less than 10%, which indicated that the laparoscopic approach was indeed feasible and safe. In Sweden, another pioneer, Lönroth, used manual suture technique to connect an antecolic jejunal loop to the proximal pouch in a small series of six patients^[14]. In 2003, the Gothenburg group could report comparable long-term weight loss in the first 76 consecutive laparoscopic GBP-patients to open procedures^[15]. Other authors have followed with large series of laparoscopic gastric bypass procedures with excellent results. In a well-known series of 400 patients, Higa *et al*^[16] reported very low complication rates, and no leakages at the gastrojejunal anastomosis. They could also demonstrate maintained excess weight loss at 3 years after laparoscopy in one of the largest series at that time^[17]. To shorten the learning curve, hand-assisted laparoscopy, allowing the surgeon to have a helping hand in the abdomen, was used in some centres, but neither costs, nor length of stay was favourable to total laparoscopy^[18,19].

In the modern version, Roux-en-Y Gastric Bypass, a divided jejunal loop (Roux-limb) is connected to a gastric pouch, based on the lesser curvature. A small gastric pouch is believed to facilitate long-term weight-loss and reduce the frequency of anastomotic ulcers in the acid-vulnerable jejunal mucosa. The gastrojejunostomy, the most critical part of the procedure, has been performed by different techniques, circular and linear stapler, and a totally hand-sewn, all having their specific pro and cons. In short, a more manual technique, gives the surgeon improved control, but at the price of increased technical demand and operative time. Systematic reviews have concluded that linear stapling for the gastrojejunostomy will reduce the frequency of strictures, surgical wound infections and operative time^[20]. The placement of the Roux limb, antecolic antegastric, retrocolic antegastric, or retrocolic retrogastric, is determined by the surgeon's preference. Laparoscopic gastric bypass was soon proved to be feasible and safe in the surgical treatment of morbidly obese patients, and often referred to as "gold standard" in bariatric surgery.

Parallel to this, the laparoscopic approach was also adopted for VBG with early publications from Italy, United States and Sweden^[21-23]. Lönroth *et al*^[22] reported that in 38 laparoscopically operated patients, the postoperative course was characterised by less postoperative pain, earlier mobilization, and an improved respiratory function compared to patients operated on with an open VBG. A shorter and less cumbersome postoperative period was soon noted^[22-24], as well as similar weight loss compared to conventionally operated patients.

In early studies by Fried *et al*^[25,26], laparoscopic placement

of fixed gastric bands resulted in less wound-associated complications and incisional hernias than an open surgery. The frequent problem with intraoperative calibration of the fixed bands^[27], was solved with a brand new product, designed specifically to be inserted by minimal invasive techniques, the Adjustable Gastric Band (AGB). Pioneering work on the laparoscopic adjustable gastric band was performed in Italy, Belgium and Sweden^[28-32]. In clinical practice, laparoscopic adjustable gastric banding boomed during the coming decade. However, in retrospect, reports on technical problems with slippage and pouch dilatation as well as reflux problems and disappointing long-term results^[33] were soon published. The reoperation rate was later found to be high, 40%-50%^[34,35] and the weight result rather poor, 30%-50% excess weight loss. In Europe, the heyday came to a stop, and laparoscopic adjustable gastric banding was abandoned in many countries, *e.g.*, France from 84% to 25% in 2005-2011^[36]. In 2001, laparoscopic adjustable gastric banding had a revival in the US, when approved by the Food and Drug Administration (FDA). Banding quickly took almost half the market in the former GBP-dominated country. The comeback was relatively short as similar results to the European were presented in the US, inferior weight loss and more long-term complications^[37,38] compared to the American gold standard, laparoscopic gastric bypass.

In 1998, Ren *et al*^[39] published the first series of laparoscopic duodenal switch, a technically demanding procedure reserved for laparoscopic experts. In 2003, the possibility of a two-stage procedure in super-super obese patients was suggested to overcome technical difficulties^[40]. The idea was to first transform the stomach into a gastric sleeve, creating a 40-50 kg weight-loss, thus facilitating the later division of the duodenum and anastomosis to the ileum. However, many patients did not return for the planned second stage, satisfied by their initial weight loss, and a new stand alone procedure was born, the laparoscopic Sleeve Gastrectomy (SG). In SG, the risk for nutritional deficiencies is reduced, as patients have an intact gastrointestinal tract, except for the reduced gastric volume. The number of laparoscopic SGs have increased dramatically in the US, replacing AGB, even though some technical details under discussion, for example in reducing the frequency of postoperative reflux (Figure 1).

Success of laparoscopic bariatric surgery

The first years of this millennium were characterized by large and refreshing publicity on bariatric surgery in both medical and lay literature. In the end of the 1990s, several celebrities, having had laparoscopic bariatric surgery, spoke out in media and across the internet. This was in great contrast to what the pioneers had endured in prior years. Suddenly, the laparoscopic approach was accepted by the public and the number of bariatric procedures rocketed. In the US, the percentage of laparoscopic-GBP increased from 1.5% to 17.1% between 1998 and

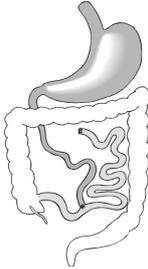
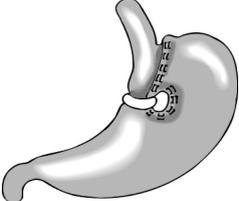
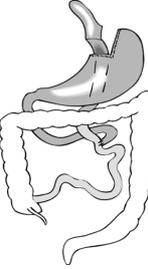
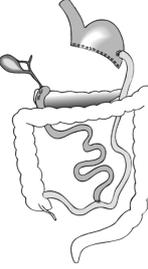
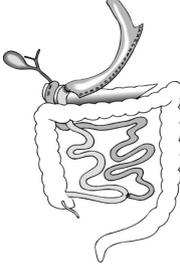
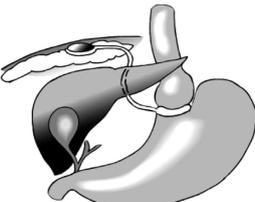
Procedure and working mechanism	First report	Laparoscopic pioneers
 <p>Jejunum-ileal bypass, JIB Reduced length of small bowel</p>	1954, Kremen	-
 <p>Vertical banded gastroplasty, VBG Narrow passage into the stomach</p>	1970, Mason	Catona, Chua, Morino, Lönroth
 <p>Gastric bypass, GBP Stomach excluded</p>	1967, Mason	Higa, Schauer, Wittgrove, Lönroth
 <p>Bileo-pancreatic diversion, BPD Reduced gastric volume and small bowel length</p>	1972, Scopinaro	Scopinaro, Paiva
 <p>Duodenal switch, DS Reduced gastric volume and small bowel length</p>	1984, Marceau 1988, Hess	Gagner
 <p>Adjustable gastric banding, AGB Reduced passage into the stomach</p>	1994, start of pioneering laparoscopic work	Morino, Belachew, Favretti, Forsell Catona

Figure 1 Landmarks for important bariatric procedures, jejunum-ileal bypass, vertical banded gastroplasty, gastric bypass, bileo-pancreatic diversion, duodenal switch, and adjustable gastric banding, including schematic drawings.

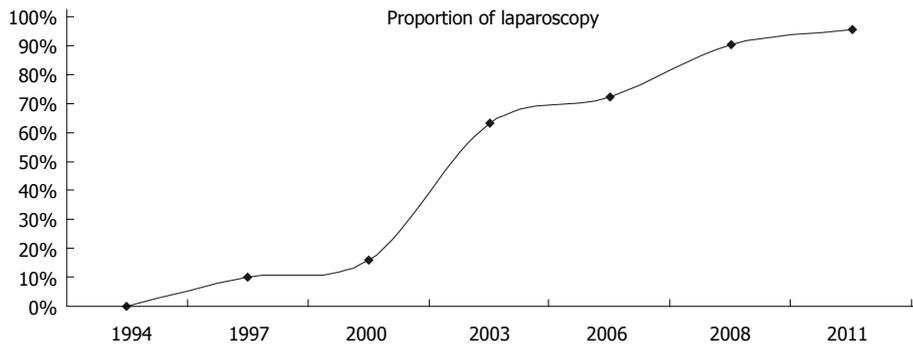


Figure 2 Proportion of bariatric surgery that was performed with laparoscopic approach world wide. In 2003-2008, a concurrent increase from 146000 to 340000 annual procedures was seen.

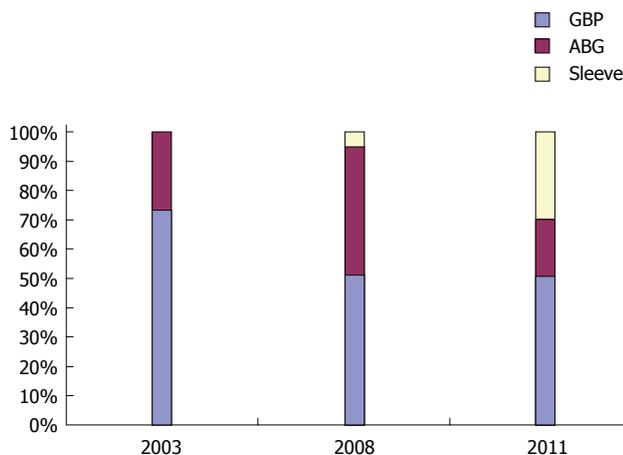


Figure 3 Proportion of the three major bariatric procedures, gastric bypass, adjustable gastric banding, and sleeve gastrectomy, performed world wide 2003-2011. Major part, but not all are performed with laparoscopic technique. Data are adopted from Buchwald *et al*^[42,43,47].

2003^[41]. In consecutive reviews, Buchwald *et al*^[42,43] have been able to present unique world-wide data on all bariatric surgery performed in the individual nations belonging to the International Federation for the Surgery of Obesity, IFSO. The proportion of laparoscopic bariatric surgery rose from 63% in 2002-2003 to over 90% in 2008, as demonstrated in Figure 2. From nearly nothing to 90% in a decade, a truly remarkable result. Compared to other abdominal procedures, the laparoscopic technique was estimated to have surpassed open surgery for cholecystectomy in 1992, reflux surgery in 1996 and bariatric surgery in 2005, followed by appendectomy in 2006 and colectomy in 2009^[44] (Table 1). The progress in bariatric surgery is impressive as laparoscopy in morbidly obese patients is technically demanding, and that the procedures in themselves are more complex, *e.g.*, requiring stapling, handling of the small bowel and construction of anastomoses, compared to the other procedures, addressing only one organ, in addition often resected. In spite of the switch to laparoscopy, mortality in bariatric surgery has remained low or even decreased^[45], and is today similar to cholecystectomy^[46]. As a result, laparoscopic surgery is the natural choice for most patients and

surgeons, regardless of the type of procedure.

As a consequence to the remarkable development in laparoscopy, the number of bariatric procedures have increased world wide. In the above mentioned reviews by Buchwald^[43], a doubling was seen in the IFSO-nations, from 146000 to 340000 procedures in 2003-2008. In the US, a ten-fold increase has been seen, reaching 200000 annual bariatric procedures, mainly performed by laparoscopy. In Europe, around 50-100 bariatric procedures are presently performed per 100000 inhabitants in many countries^[47]. Worldwide 2003-2011, AGB decreased sharply with a concomitant increase in SG, from 0% to 25%, with GBP increasing slightly. No other procedure exceeded 2%-3% (Figure 3). In Europe, AGB had a large drop and for example in Sweden, laparoscopic GBP constitutes of 97% of all bariatric surgery in 2013.

Advantages with laparoscopy

In general, the introduction of laparoscopy in bariatric surgery has reduced wound-related complications and improved patient recovery^[48], identical to most other procedures such as laparoscopic cholecystectomy and appendectomy^[49]. In addition, laparoscopy reduced the earlier high frequency of incisional hernias. Mortality was found to be lower for laparoscopic procedures than for open surgery, 0.16% and 0.41%, respectively^[50]. Overall, the reduced perioperative risks and improved patient recovery after laparoscopy have been well documented and outweigh the potential procedure-related risks. Super-obese patients (BMI > 50) have, however, been associated with increased length of stay and 30-d mortality (0.26% *vs* 0.07%) after bariatric surgery, compared to morbidly obese, although, the overall complication rates and mortality was low^[51]. As the minimal invasiveness of laparoscopic surgery has made two-stage procedures possible, super obese patients can be treated by an initial sleeve gastrectomy, and after 40-50 kg of weight loss, have the second part of a duodenal switch, without the surgeon fighting dense adhesions. Postoperative systemic inflammation is lower after laparoscopy than open surgery, with less increase in total white blood cell count as well as segmented neutrophil cells and C-reactive protein (CRP)^[52]. The reduced inflammation

Table 1 Evolution of laparoscopy for common procedures in general surgery

	First reported (yr)	Laparoscopy > open (yr)	Laparoscopy	Conversion to open	Complication	Mortality	Length of stay (d)
Cholecystectomy	1989	1992	77%	15%	4%	0.3%	2
Reflux	1991	1996	84%	3%	4%	0.2%	3
Bariatric surgery	1994	2005	94%	1%	2%	0.1%	2
Appendectomy	1983	2006	80%	2%	1%	0.0%	2
Colectomy	1991	2009	52%	14%	6%	0.4%	5

For each specific procedure, data on first report, year when laparoscopy surpassed open technique in the United States, and general result are presented. Data from the University Health System Consortium database, containing > 100000 of the five specific procedures in 2008-2012, and adopted from Nguyen *et al*^[44].

and minimal invasiveness, makes surgeons more willing to take the patient back to the operating room and “drop in a scope”, than to reopen a large abdominal incision to check for leakage.

In a systematic review of fast-track laparoscopic bariatric surgery, next-day discharge was possible in 81%-100% after GBP^[53]. These promising results led to the possibility of day-care surgery (< 23 h), an impossible idea only a decade ago. In a systematic search published in 2011^[54], 84% of all intended day-care laparoscopic GBP could return home within 23 h as planned, with only 1.8% of the patients readmitted. Thanks to its minimal invasive nature and good results, laparoscopic GBP has also been used with good results in obese adolescents^[55] and older patients, above 60-70 years^[56].

Special demands in laparoscopy

In general, laparoscopy is a high-tech procedure requiring a thin laparoscope, 5-12 mm, with a strong light source, video processor and high-quality video screens. To obtain working space in the abdomen; a pressure-triggered gas insufflator with gas-tight trocars, however, allowing smooth passage of specially designed instruments of different diameters, is needed. Laparoscopic procedures are technically more demanding for the surgeon, because of the loss of sensation and high demand of eye-hand coordination for safe use of the intraabdominal instruments. Not only the surgeon, but the whole team needs to be familiar with the special setting. In a study by Stepaniak *et al*^[57], working with fixed teams in laparoscopic bariatric surgery reduced duration of the procedure, improved teamwork and safety climate.

Laparoscopic surgery has some specific drawbacks. First, in entering the abdomen, a complete new problem has evolved, the blind entry of the first trocar. Injuries to the aorta and other intraabdominal organs have been described, often leading to severe complications, if not treated correctly^[58]. Second, in bariatric surgery, the enlarged left liver lobe obscures the area around the gastro oesophageal junction, where the most complicated parts of the procedure is done. To overcome this, most surgeons pre-treat their patients by a 2-4 wk long preoperative low calorie diet, as this results in improved visualisation and reduced operative time^[59], mainly by reducing the intrahepatic fat. Third, the most devastating

complication is however, incarcerated internal hernias behind a transposed small bowel loop. When two small bowel loops are brought together, a defect will occur between the two mesenteries, and this space will enlarge during the weight loss. As the formation of adhesions is reduced compared to open surgery, the small bowel is more prone to slide into the opening. This will result in colicky pain, often aggravated after meals, prompting a CT-scan or diagnostic laparoscopy. If treated early, the entangled small bowel loops can be retracted and the defect closed, otherwise a massive gangrene can occur due to ischemia. The later patients suffer the risk of developing a short bowel syndrome, often needing revision of the bariatric operation to reduce the need for parenteral nutrition.

We cannot make significant technical changes to well-proved procedures, just to be able to perform them by laparoscopy. The technical difficulties during the initial learning curve in laparoscopic surgery led to a number of malpractice cases and increased attention by press and plaintiff attorneys, threatening the entire process. In addition, patients interested in the aesthetic advantages and enhanced recovery might not see laparoscopy as “a real operation”. To avoid misunderstandings, surgeons must take special care in preparing them for the possibility of conversion to open surgery as well as discussing potential severe short- and long-term complications. Finally, young surgeons, skilled in laparoscopy, might not be comfortable in converting a procedure into open surgery, especially in an emergency situation.

FUTURE DEVELOPMENT

Two new techniques, robotic-assisted laparoscopy and single incision laparoscopic surgery (SILS), is being developed. In robotic-assisted laparoscopy, the assistant is replaced by a high-technological mechanical device; otherwise the procedure is performed identically as in conventional laparoscopy. In two recent reviews^[60,61], no clear reduction in complications or operative time could be seen. However, the learning curve could be shorter, possibly because of superior imaging and freedom of movement compared to traditional laparoscopy. In SILS, a multi-channel trocar is placed in the umbilical region, to reduce the number of trocars and improve cosmetics.

Postoperative use of opiates have shown to be reduced, however, operative time is, so far, similar or longer to conventional laparoscopy^[62]. Improved trocars, to increase the working space for hands and instruments around the SILS-device outside of the abdomen, are under development. The latest minimal invasive technique, natural orifice transluminal endoscopic surgery (NOTES), in which the abdominal cavity is entered through, for example, the stomach or vagina, results in total scar-free surgery. NOTES has been used in appendectomy, but also in bariatric surgery, e.g., sleeve gastrectomy^[63], but is not ready for routine use.

Furthermore, the remarkable effect on metabolic diseases, in addition to massive weight loss, will bring the laparoscopic bariatric procedures into a new era. Early studies and recent randomised controlled trials by Schauer and Mingrone^[64,65] have proven bariatric surgery to be superior in achieving complete remission of adult-onset diabetes, even in patients with a BMI of 30-35. This opens a large new field for surgical treatment for chronic, metabolic diseases in obese and non-obese patients, by adopting the minimal-invasive bariatric procedures, thus going beyond weight loss into metabolic surgery. The laparoscopic revolution might therefore, not only have improved quality of life and longevity for obese patients, but ultimately decrease the cost of health care. Who could have predicted this development, when the pioneering work was started in the mid of the 20th century?

CONCLUSION

Bariatric surgery has been investigational. Pioneers have continuously sought for an ideal procedure in order to relieve morbidly obese patients from their comorbid conditions, and to increase life expectancy and quality of life. The ideal procedure should also have low risk of complications, both in short- and long term, and minimal negative impact on daily life. In only a decade, laparoscopic techniques have revolutionized bariatric surgery, reducing operative time, length of stay, and risk for complications, without hampering long-term benefits. The laparoscopic revolution has also resulted in a vast increase of the number of bariatric procedures performed world-wide. At present, technical improvement of instruments and techniques for further minimizing the abdominal entry is in focus. The next revolution, adopting minimal invasive bariatric procedures as treatment for type 2 diabetes and other metabolic diseases, is about to start.

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