12 Methods of Reconstruction—BI, BII, Roux-en-Y, Jejunal Interposition, Proximal Gastrectomy and Pouch Reconstruction

Daniel E. Stange and Jürgen Weitz

Introduction

Removal of parts or the whole stomach due to stomach cancer or benign diseases is normally followed by the reconstruction of the digestive tract continuity (Fig. 12.1) [1]. Several different approaches have been described to achieve this goal [2–9]. Decisive factors that have to be taken into account when deciding on the type of reconstruction include functional outcome, the morbidity rate of the procedure, and the life-time expectancy of the patient. The functional outcome includes the possible postoperative diet and resulting nutritional status of the patient and his quality of life. The morbidity rate as well as the associated mortality rate depends on the complexity of the procedure, i.e., the formation of a pouch or the inclusion of a duodenal anastomosis. The life-time expectancy needs to be balanced with the morbidity rate, favoring a rather simple reconstruction for patients presenting with advanced diseases. The availability of randomized controlled trials (RCTs) evaluating different aspects of the competing reconstruction techniques enables shared decision making, taking into account the individual case and evidence-based surgery.

J. Weitz (✉) · D. E. Stange
Department of Visceral, Thoracic and Vascular Surgery, University Hospital Carl Gustav Carus, Technical University Dresden, Fetscherstr. 74, 01307 Dresden, Germany
e-mail: juergen.weitz@uniklinikum-dresden.de

Reconstruction Following Distal Gastrectomy

Methods for Reconstruction

Distal gastrectomy (Fig. 12.1c) includes all procedures that leave the esophago-gastral junction intact, i.e., antrectomy, 2/3 and 4/5 gastric resections. The following reconstructions are most frequently used:

- Billroth I, characterized by a gastro-duodenal anastomosis
- Billroth II, characterized by a gastro-jejunostomy of the remaining stomach to the first jejunal loop
- Roux-en-Y, characterized by a gastro-jejunostomy of the remaining stomach to an excluded jejunal limb and an end to side jejuno-jejunostomy between the excluded jejunum to the first jejunal loop

Billroth I

The reconstruction according to Billroth I (BI) was first performed in 1881 and is characterized by an anastomosis between the remaining stomach and the duodenum (Fig. 12.2a) [10]. Potential advantages of this procedure include the maintenance of a physiological gastro-duodenal passage of the food. Nevertheless, the BI reconstruction is restricted to cases with a limited resection of the distal stomach due to the restricted mobilization possibilities of the duodenum and remaining stomach to establish a tension-free anastomosis. Furthermore, a limited distal resection is contra-

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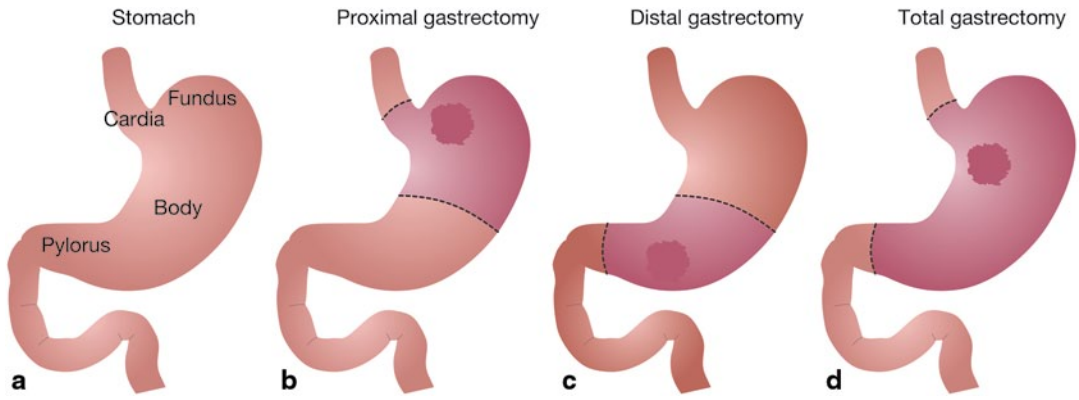

Fig. 12.1 Anatomy and resection procedures of the stomach. **a** The four sections of the human stomach. **b** Schematic drawing of proximal gastrectomy. **c** Schematic drawing of distal gastrectomy. **d** Schematic drawing of total gastrectomy

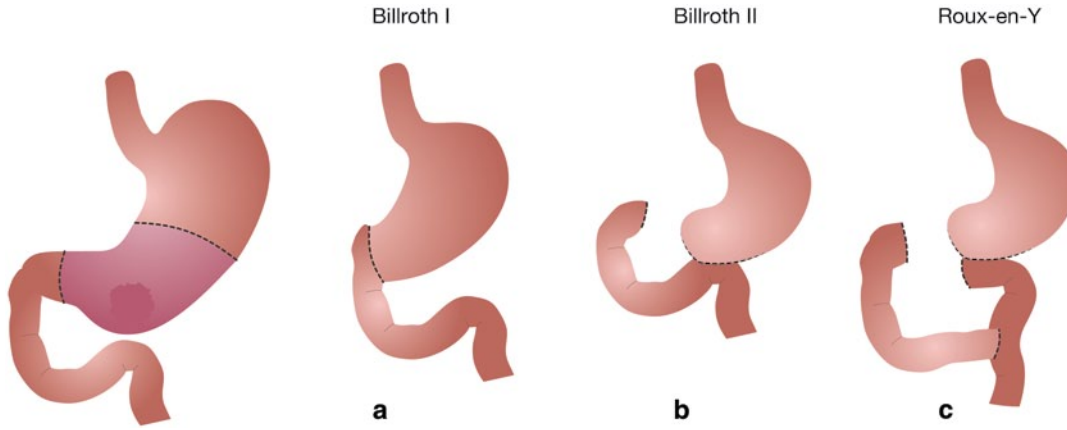

Fig. 12.2 Reconstruction following distal gastrectomy. **a** Schematic drawing of Billroth I reconstruction. **b** Schematic drawing of Billroth II reconstruction. **c** Schematic drawing of Roux-en-Y reconstruction

indicated in most cases of invasive stomach cancer, thus leaving the BI reconstruction an option mainly after resection of benign lesions, noninvasive tumors, or early malignant lesions. It should be noted, that this type of reconstruction, although commonly not used in Western countries, is an often used mode of reconstruction in Asia.

Billroth II

The reconstruction according to Billroth II (BII), first performed in 1885, is characterized by a gastro-jejunostomy of the remaining stomach to the first jejunal loop (Fig. 12.2b) [11]. The advantage of this procedure in comparison to BI is the tension-free anastomosis. The main disadvantage is the un-physiological passage of the bilio-pancreatic juice through the stomach due to the missing pylorus. Some patients develop the so-called afferent loop syndrome (ALS), which is caused by an accumulation of bilio-pancreatic juice in the afferent jejunal segment due to a hampered drainage that leads to pain, nausea, and vomiting.

Roux-en-Y

The Roux-en-Y (RY) reconstruction was first described by Woelfler in 1883 [12] and later popularized by C. Roux from 1893 onwards [13]. The Roux-en-Y reconstruction is characterized (after distal resection) by a gastro-jejunostomy of the remaining stomach to a jejunal limb (mostly the second jejunal loop), which has been excluded from the normal intestinal passage (Fig. 12.2c).

The procedure involves the blind closure of the proximal duodenum and a second anastomosis between the ascended jejunal limb and the first jejunal loop that carries the bilio-pancreatic juice. The main advantage of the procedure is the reduction of bilio-pancreatic reflux into the stomach due to the distance between the stomach and the jejuno-jejunostomy, which normally has a length of at least 40 cm. The main disadvantage is the exclusion of the duodenal segment from the normal intestinal passage. This exclusion might be the reason for the development of the so-called Roux syndrome in up to 10% of patients, characterized by a delayed emptying of the stomach into the efferent jejunal loop in the presence of a nonconstricted gastro-jejunal anastomosis.

Summary of Data from Clinical Trials Comparing Reconstructions After Distal Gastrectomy

A meta-analysis concentrating on the comparison of BI vs. RY for reconstruction after distal gastrectomy for stomach cancer combined three RCTs [14]. In addition, this study also performed a meta-analysis on nine observational clinical studies (OCTs). Not all parameters were available in all RCTs. A significant difference in favor of a RY reconstruction compared to BI could be detected for bile reflux (2 RCTs, 71 vs. 75 patients) and remnant gastritis (2 RCTs, 181 vs. 182 patients), while operation time and hospital stay were significantly longer after RY vs. BI (3 RCTs, 240 vs. 238 patients). Of note, reflux esophagitis showed only a tendency, but was not significantly lower after RY (3 RCTs, 227 vs. 231 patients). This trend is substantiated by a significant reduction of reflux esophagitis after RY vs. BI in the meta-analysis of OCTs (5 OCTs, 322 vs. 397 patients). The anastomotic leak rate and anastomotic stricture rate was equally high in both reconstructions (3 RCTs, 240 vs. 238 patients). Taken together, the meta-analysis demonstrated clinical benefits concerning the reduction of bile acid reflux and its consequences for a RY compared to a BI reconstruction.

A second meta-analysis comparing BI or RY including RCTs of distal gastrectomies of both nonmalignant and malignant patient cohorts is available [15]. This meta-analysis did show no significant difference in total postoperative complications or specifically in the anastomotic leak rate in RY vs. BI (4 RCTs, 185 vs. 189 patients). A significant lower rate of reflux symptoms (5 RCTs, 381 vs. 391 patients), reflux esophagitis (6 RCTs, 340 vs. 372 patients), and gastritis (7 RCTs, 337 vs. 377 patients) was found after RY reconstruction vs. BI, while no difference for dumping syndrome was detected (5 RCTs, 361 vs. 391 patients). No significant difference for operation time was evident (3 RCTs, 106 vs. 114), patients after RY vs. BI had a significantly shorter hospital stay (2 RCTs, 91 vs. 91 patients).

The same publication also reported a meta-analysis comparing RY vs. BII reconstructions. No significant differences in total postoperative complications (2 RCTs, 65 vs. 61 patients), while dumping syndrome (2 RCTs, 83 vs. 78 patients), reflux symptoms (2 RCTs, 83 vs. 78 patients), reflux esophagitis (3 RCTs, 60 vs. 68 patients), and gastritis (6 RCTs, 114 vs. 148 patients) were significantly lower in RY vs. BII reconstructed patients.

A third meta-analysis within the same publication compared BI vs. BII reconstructions. While significantly less overall complications (4 RCTs, 738 vs. 280 patients) as well as specifically less anastomotic leaks (3 RCTs, 708 vs. 248 patients) were found in BI vs. BII reconstructed patients, the mortality rate was not significantly different (3 RCTs, 697 vs. 258 patients). Of note, the local recurrence rate was significantly higher after BI vs. BII reconstruction (2 RCTs, 71 vs. 75 patients). Concerning reflux symptoms (2 RCTs, 66 vs. 39 patients), dumping syndrome (2 RCTs, 66 vs. 39 patients), reflux esophagitis (3 RCTs, 68 vs. 67 patients), and gastritis (5 RCTs, 113 vs. 106 patients) no significant differences were found between BI and BII reconstructions.

Evidence Based Recommendations for the Reconstruction After Distal Gastrectomy

As mentioned above, BI reconstruction is only possible in a minority of cases after distal gastrectomy due to the restricted possibilities to mobilize the duodenum and gastric remnant. Two studies comparing BI vs. BII both reported a higher incidence rate of local recurrence after BI, indicating that resection margins and lymph node dissection might have been chosen too limited in order to perform a tension-free anastomosis. As both BI and BII are associated with similar mortality rates as well as symptoms and consequences of bilio-pancreatic reflux, the BI reconstruction is rarely used for malignant diseases in Western countries.

Both the BI and the BII reconstruction have been shown to be inferior in preventing the symptoms and consequences of bilio-pancreatic reflux when compared to RY reconstruction. As the overall survival of patients depends mainly on a radically performed oncological resection, which is in the case of a planned BII or RY not restricted in its dimension, the decision on one of the two reconstruction techniques should be based on the postoperative complication rate and quality of life. As morbidity rates are similar while symptoms resulting from bilio-pancreatic reflux are significantly higher after BII, a RY reconstruction should be favored.

Reconstruction Following Proximal Gastrectomy

Methods for Reconstruction

Proximal resections (Fig. 12.1b) have seen a revival in recent years due to the high number of early gastric cancers in Asian countries that demand a more limited resection than total gastrectomy due to their low frequency of lymph node metastasis [16]. Reconstruction after proximal gastrectomy was initially performed as a direct esophago-gastrostomy, but this procedure comes along with a high rate of gastric reflux [17]. To prevent the occurrence of gastric reflux, different approaches have been tested, including combining a esophago-gastrostomy with a fundoplication [18], jejunal interposition with and without pouch [19, 20], double tract reconstruction [21], and ileo-colic interposition [22]. To date, only a few nonrecurrent RCTs have been performed, often reporting on few patients only [18–21]. Of note, two RCTs have been published on the topic of including a pouch or not: both favor a pouch when performing a jejunal interposition [19, 20]. With proximal resections becoming the standard operation for early proximal gastric cancers at least in Asia, more RCTs analyzing different reconstruction methods are expected to be conducted within the next years. Currently, no evidence-based advice can be given upon which procedure to favor.

Reconstruction Following Total Gastrectomy

Methods for Reconstruction

Total gastrectomy (Fig. 12.1d) is performed in all cancer patients where a distal or proximal gastrectomy cannot be performed due to oncological radicalness concerning the distance of resection margins towards the tumor, i.e., in adenocarcinomas greater than T2 of the proximal stomach, hereditary (CDH1 mutated) diffuse gastric cancer or signet ring gastric cancer with an insufficient proximal margin. The following reconstructions are most frequently used:

RY is characterized by an esophago-jejunostomy of the remaining esophagus to an ascended jejunal limb and a jejuno-jejunostomy between the ascended jejunum to the first jejunal loop. The reconstruction can be performed with and without a pouch.

Jejunal or colonic interposition: in the first case characterized by an esophago-jejunostomy and a jejuno-duodenostomy of an interposed jejunal segment. The formation of a pouch can be included in the reconstruction. Similarly, a segment of the colon, i.e., the transverse colon or an ileo-cecal segment can be interposed.

Roux-en-Y

The RY reconstruction after total gastrectomy is similar to the RY after distal gastrectomy and has been described first by Orr in 1947 [23]. The technique is similar to the RY after distal gastrectomy and consists of the formation of an esophago-jejunostomy of the remaining esophagus to a jejunal limb, which has been brought up either via the retrocolic (transmesocolic) or antecolic route (Fig. 12.3a). The length of the jejunal segment that has been brought up and thus excluded from the original small intestinal passage is often longer than in the case of RY reconstruction after distal gastrectomy. The esophago-jejunostomy is commonly performed as an end-to-side anastomosis, resulting in a blind ending of the jejunum (jejunal stump), which should be as short as possible.

Jejunal and Colonic Interposition

In order to keep the duodenum in the continuity of the intestinal passage the interposition of a jejunal segment after a partial removal of the stomach has already been used by Roux in 1907 [24]. Longmire was the first to apply this technique after total gastrectomy [25] (Fig. 12.3b). The interposition requires the identification of a long enough jejunal segment (25–30 cm) close to the ligament of Treitz fed by a sufficient jejunal artery. Two anastomoses (a proximal esophago-jejunostomy and a distal jejuno-duodenostomy) re-establish the continuity of the intestinal continuity. Different parts of the colon have also been used to replace the missing stomach [26, 27]. The interposition of a colonic segment is technically more demanding and has not been shown to bring advantages over the jejunal interposition in a randomized trial.

Reconstruction with a Reservoir Formation

In order to re-establish both the intestinal continuity and the physiological function of the stomach to store food, the RY and the jejunal interposition reconstruction have been combined with the formation of a pouch reservoir as a stomach substitute. In addition, also colonic segments have been used for reservoir formations. Multiple different approaches have been described in the literature for the formation of a reservoir, several of them evaluated in RCTs.

Roux-en-y with Pouch

RCT-evaluated reconstructions include the formation of a J-pouch [28, 29], a Ω-pouch [30], a S pouch [31], and an aboral pouch [32]. The formation of a J-pouch involves a side-to side entero-enterostomy of the jejunum and a prolonged jeju-

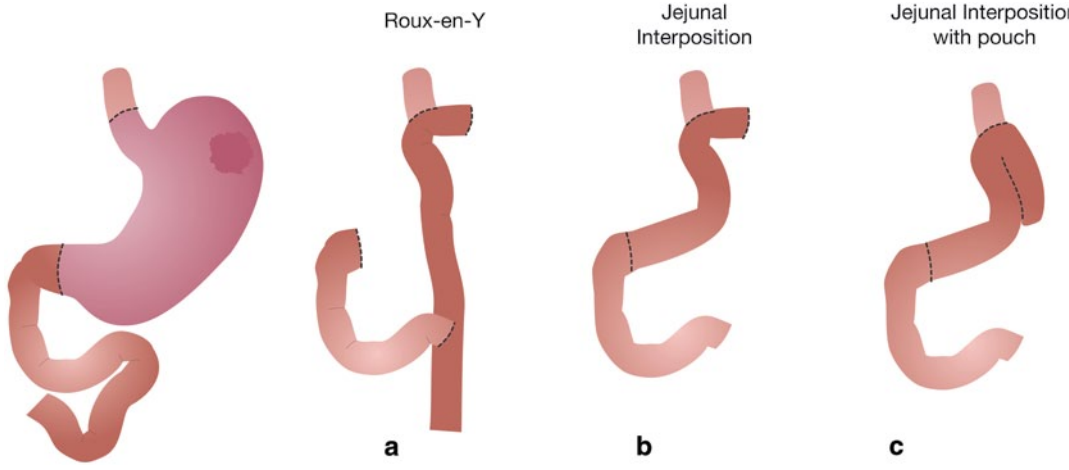

Fig. 12.3 Reconstruction following total gastrectomy. **a** Schematic drawing of Roux-en-Y reconstruction, **b** Schematic drawing of jejunal interposition, **c** Schematic drawing of jejunal interposition with pouch

nal stump all the way to the esophago-jejunostomy with a total length of 15–20 cm (Fig. 12.4a). The Ω-pouch differs from the J-pouch in that the entero-enterostomy is not extended completely to the esophago-jejunostomy (Fig. 12.4b). The S-pouch is formed by accomplishing two entero-enterostomies at the end of the ascended jejunum (Fig. 12.4c). The aboral pouch is formed by fashioning, instead of a simple end-to-side Y-anastomosis of the afferent and efferent jejunal limbs, a long (15 cm) side-to-side antiperistaltic jejuno-jejunostomy (Fig. 12.4d).

Jejunal Interposition with Pouch

Several duodenal passage-preserving reconstruction techniques including the formation of a pouch have been described, the earliest dating back to the 1950s [33, 34]. Only one reconstruction technique, the J-pouch combined with jejunal interpositions has also been evaluated by RCTs (Fig. 12.3c).

Ileo-Cecal Interposition

The idea of using the ileo-cecal valve as a substitute for the cardiac sphincter has first been published by Lee [35] and Hunnicutt [36]. Both authors used an interposition of the terminal ileum and the cecum to bridge the gap after total gastrectomy. This technique is the only one published until today which attempts to include an anatomic barrier between the neo-stomach and the esophagus to prevent bilio-pancreatic reflux. In addition, the colonic segment by nature functions as a kind of reservoir due to its larger diameter when compared to a simple jejunal interposition. No data from randomized controlled studies in humans is available. Nonetheless, data from mini-pigs after distal resection [37] and prospective and retrospective studies on patients after total gastrectomy [22, 38] indicate a good functioning of the ileo-cecal valve as an antireflux barrier. Nevertheless, the technically demanding and thus morbidity-prone operation has not been evaluated in RCTs.

Summary of Data from Clinical Trials Comparing Reconstructions After Total Gastrectomy

Reconstruction With or Without a Reservoir

A meta-analysis identified 13 RCTs (search until October 2008) addressing this question [39]. Nine RCTs compared Roux-en-Y reconstruction with (PRY) and without pouch (RY). Not all trials reported on all analyzed parameters. Seven RCTs could be combined for the analysis of morbidity or mortality. No significant difference could be shown for PRY vs. RY (187 vs. 200 patients). Operation time (3 RCTs, 58 vs. 44 patients) and

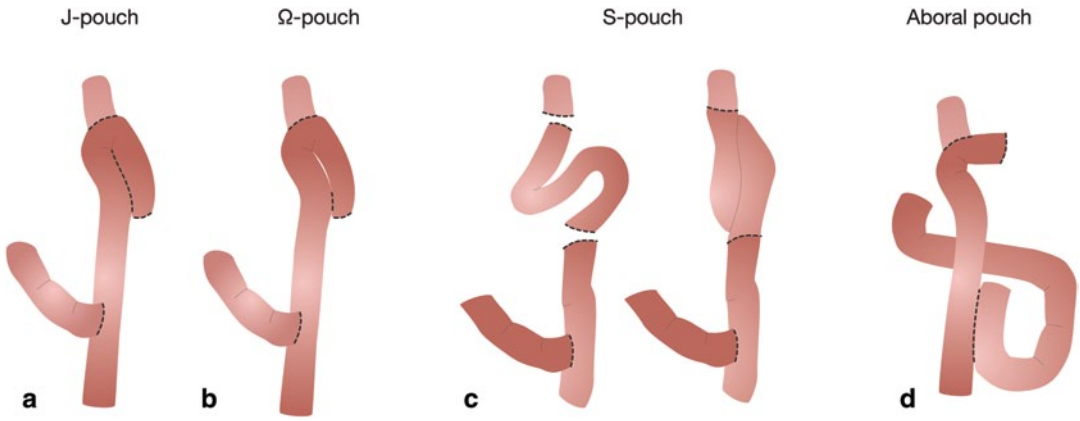

Fig. 12.4 Roux-en-Y reconstruction with a reservoir formation. **a** Schematic drawing of a J-pouch, **b** Schematic drawing of a Ω-pouch, **c** Schematic drawing of a S-pouch, **d** Schematic drawing of an aboral-pouch

hospital stay (two RCTs, 34 vs. 32 patients) did not increase significantly in PRY vs. RY. Dumping syndrome was significantly lower in PRY vs. RY 6 months (2 RCTs, 33 vs. 29 patients) and 12 months postsurgery (4 RCTs, 58 vs. 51 patients). Reflux was significantly lower in patients after PRY vs. RY 12–15 months postsurgery (2 RCTs, 19 vs. 18 patients). A tendency towards better food intake (measured as > or < than 50 % of preoperative value) for PRY was observed at 3 and 6 months, while food intake was significantly better in PRY vs. RY at 12–15 months postsurgery (3 RCTs, 42 vs. 32 patients). Concerning the quality of life two RCTs used the same score and could be combined. No difference was detected when all patients were analyzed at 6, 12, and 24 months (2 RCTs, 72/52/35 vs. 66/46/33 patients). Nevertheless, both studies independently described significant differences in favor of a pouch at 24 and 30–60 months. If only patients with R0 resection in one trial and 5-year survival of the other trial were combined, a significantly better quality of life was achieved in RYP vs. RY at 12 and 24 months (2 RCTs, 33/22 vs. 29/22 patients).

Four RCTs compared jejunal interposition with (JPI) and without (JI) pouch. Due to heterogenously reported parameters a meta-analysis could only be performed for mortality, which showed no significant difference between JPI vs. JI (3 RCTs, 67 vs. 46 patients).

Preservation of the Duodenal Passage

Nine RCTs compared duodenal preserving reconstructions (DP) by jejunum interposition with and without pouch to nonduodenal preserving (NDP) Roux-en-Y reconstruction with and without pouch. These studies have been jointly analyzed in a meta-analysis (search until May 2012) [40]. Four RCTs could be analyzed for morbidity differences between DP and NDP (148 vs. 153 patients), and 5 RCTs could be analyzed for mortality differences (169 vs. 176 patients), resulting in no statistical difference between the 2 procedures. Operation time was significantly longer in DP vs. NDP (6 RCTs, 207 vs. 222 patients). Body weight could be analyzed in 2 studies (DP 83 vs. NDP 84 patients) at 3 and 6 months, showing a statistically significant increased weight in DP. Four studies statistically described body weight development at different later time points, precluding a formal meta-analysis. Nevertheless, each study reported no statistical difference at time points >12 months postsurgery. Bilio-pancreatic reflux was analyzed in 2 and for 1 time point in 3 RCTs, showing no difference between DP and NDP at 3, 6, 12 and 24 months (20/20/30/19 vs. 22/22/32/21 patients). The incidence of dumping syndrome was significantly lower in DP vs. NDP at 3, 6, and 24 months (3 RCTs, 95/95/95 vs. 102/102/101 patients), but not at 12 months with the inclusion of one more trial (4 RCTs, 105 vs. 112 patients). Of note, when only RCTs which included a pouch were analyzed, no statistical difference between DP vs. NDP could be detected (2 RCTs for 3, 6, 24 months with 20/20/19 vs. 30/30/28 patients and 3 RCTs for 12 months with 30 vs. 50 patients). Quality of life could not be analyzed in a combined fashion due to different measurement scales. Of 5 RCTs, only 1 study showed an improved quality of life at 6 months in DP vs. NDP (24 vs. 24 patients), while all others reported no statistical difference at this, earlier, and later time points (up to 60 months).

Evidence-Based Recommendations for the Reconstruction After Total Gastrectomy

Two important questions concerning the reconstruction after gastrectomy have been addressed by meta-analyses, combining each several RCTs. Concerning the construction of a pouch, the pooled data clearly shows a clinical benefit for patients receiving a pouch together with a RY reconstruction, at least for the first postoperative year. Reflux, as well as dumping syndrome, eating capability, and quality of life are significantly better with than without pouch, while morbidity and mortality rates are similar. Data on pouch reconstruction after jejunal interposition document no increased mortality when a pouch is included, but data on postgastrectomy syndromes and quality of life are not strong enough to draw decisive

conclusions yet. Concerning the preservation of the duodenal passage, construction of a jejunal interposition with and without a pouch is not associated with a higher mortality or morbidity rate compared to RY, while operation time is significantly longer. Postgastrectomy syndromes in pouch reconstructed patients as well as quality of life did not show a benefit for jejunal interposition. Both procedures can thus be performed on par based on current knowledge.

Final Conclusion

For this chapter, the authors have tried to provide the reader with a summary of the available data on reconstruction techniques after major gastric surgery. Only data from RCTs and when possible from meta-analyses are presented. On a cautionary note: a meta-analysis can only be as good as the single RCTs included. The presented meta-analyses use stringent selection criteria on individual trials before inclusion. This, nevertheless, often results in comparisons with a restricted number of trials with low numbers of patients. This has to be kept in mind, as not finding a significant difference might be a result of the low patient numbers. Of course, notwithstanding the merits of evidence-based medicine, the individual patient has to be taken into account, balancing factors such as the preoperative state and life expectancy with the complexity and associated morbidity rate of the different reconstruction techniques.

Based on the available data the authors advocate for distal gastric resection a Roux-en-Y reconstruction. For proximal reconstruction available data do not support an evidence-based suggestion yet. For total gastrectomies equal results are obtained by either a Roux-en-Y reconstruction with a J- or Ω-pouch or a jejunal interposition with pouch.

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