Use of the remnant stomach for oesophagoplasty in patients following distal gastrectomy

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Summary

Oesophageal replacement in patients following distal gastrectomy (DGE) remains a surgical challenge, and the standard option is the colonic or jejunal transplant. However, in some cases, it is possible (or mandatory) to utilize the remnant stomach for oesophagoplasty (EP). This method preserves some advantages of the gastric EP in comparison with the bowel EP. During recent years, several papers have been published in English regarding remnant stomach EP, and different aspects of this procedure have been discussed. However, there is still no comprehensive literature review analysing the possible EP approaches using the remnant stomach. A multilingual literature search (database and manual) to collect and classify the currently available data regarding remnant stomach EP following DGE and its subsequent analysis was carried out. There are a number of principally different methods of a remnant stomach EP: (1) mobilization of the remnant stomach with the spleen and tail of the pancreas with its transposition into the left hemithorax; (2) mobilization of the remnant stomach after splenectomy; (3) implementation of a reversed gastric tube, tailored from the major curve; (4) the use of a transplant fed from the right gastric and right gastroepiploic arteries; (5) the use of a transplant fed from the left gastric and short gastric arteries; (6) complete mobilization of the remnant stomach; (7) direct revascularization of the gastric stump conduit. The excellent plastic potential and rich vascularization of the stomach justify its use for EP, even after prior DGE. The majority of the methods of gastric stump EP are less well developed but should be investigated further.

Keywords: Oesophagoplasty • Previous gastrectomy • Oesophagoplasty • Remnant stomach

INTRODUCTION

Oesophageal replacement in patients after a previous gastrectomy remains a surgical challenge. The standard approach for such cases is the reconstruction of the oesophagus using a colonic or jejunal transplant [1–15]. However, it is sometimes possible (or necessary) to utilize the remnant stomach for oesophagoplasty (EP). This method preserves some advantages of the gastric EP (it is more physiological, less traumatic and involves a limited number of anastomoses) in comparison with the bowel EP.

During recent years, several papers have been published in English regarding EP using the remnant stomach [4, 16–20], and different aspects of the problem have been discussed. However, there is still no comprehensive literature review on the subject to analyse the possible EP approaches using the remnant stomach. Little is known about the historical aspects of the gastric stomach EP.

One reason for the lack of a comprehensive review is the difficulty in identifying the available publications. A substantial number of important papers on the subject have been published in languages other than English, including Chinese, Russian and Japanese. These studies are poorly cited in the English literature. Several unique clinical case reports by Russian researchers have been published in dissertations or low maintenance monographs only [21–24].

The aim of our study was to collect and classify the currently available literature regarding remnant stomach EP following gastrectomy and to present it to the international surgical community. A multilingual literature search was carried out manually and using databases.

In this article, we sought to evaluate the potential of gastric EP in patients after distal gastrectomy (DGE). The applicability of the remaining stomach following other resection procedures (proximal gastrectomy and gastric tube EP) will be discussed in a separate publication.

At first glance, the applicability of the remnant stomach for use in oesophageal replacement is greatly limited. Its size is small, and the blood supply is reduced after right gastric and right gastroepiploic standard division, and occasionally after division of the left gastric vessels, during DGE. The main problem in the creation of an oesophageal substitute is to obtain a reasonable balance between the extent of mobilization and the need to preserve as much as possible of the transplant blood supply. Without this balance, it is difficult to achieve a smooth healing of the oesophageal anastomosis, particularly using a previously resected stomach for EP. Nevertheless, there are a number of principally different methods for remnant stomach EP. These methods have some
similarity with those for gastric EP in a non-operated stomach. The most important aspect of these similarities is the intention to save one or another vessel as the main source of the blood supply for both the whole and the resected stomach. Here, we review these methods one by one.

MOBILIZATION OF THE REMNANT STOMACH WITH THE SPLEEN AND TAIL OF THE PANCREAS

Standard methods of DGE involve the division of the right gastric and right gastroepiploic vessels. The remnant stomach circulation is provided by splenic artery branches (left gastroepiploic and short gastric arteries) and the ascending branch of the left gastric artery. In DGE for cancer, the left gastric vessels should be divided at their origin. When the remnant stomach is left gastric vessel be preserved [21, 22, 25, 26]. Thus, the main feeding vessel for the gastric stump is the splenic artery.

It is possible to pull the remnant stomach up to the level of the oesophageal resection by mobilization of the gastric stump en bloc with the spleen and pancreatic tail followed by transposition into the left pleural cavity. This procedure was first performed in 1958 by Professor A.A. Rusanov, who was, at that time, the Head of our Department. His original idea was the result of significant research. Initially, Rusanov proposed his technique of oesophageal replacement using the gastric transplant, mobilized with the spleen and pancreatic tail, for cases with an intact stomach. Rusanov’s operation was first performed in 1954 [27], and it was then successfully introduced and developed clinically [28]. This unusual technical solution allowed for substantial improvements in the circulation in the fundus of the gastric transplant and, thus, a decrease in the oesophagogastric anastomosis (EGA) leakage rate.

The history of the gastric stump EP technique developed by Rusanov and the current state of this method were described in considerable detail in our recent paper [29]. We will avoid the duplication of this information and restrict ourselves here principally to important data.

Rusanov performed the first EP using his original technique in a gastrectomized patient in 1958 for lower third oesophageal cancer. The distal oesophagus with the tumour was resected through the left thoracic approach. Then, the remnant stomach and the afferent and efferent jejunal loops were mobilized en bloc with the spleen and pancreatic tail and transposed above the diaphragm. An EGA was created below the aortic arch. Despite the development of pulmonary infection and respiratory failure, the patient gradually improved and was discharged. Two years later, Rusanov performed the second successful operation in a similar case following a Balfour-Polya (instead of a Finsterer) DGE. Both cases were published in Soviet periodicals [30, 31].

However, these publications did not receive any response from the scientific community and were not cited anywhere. The proposed technique was abandoned and eventually rediscovered by surgeons working at the Shantou University Hospital (China). They offered some modifications to Rusanov’s technique, including transection of the afferent jejunal loop close to the remnant stomach and mobilization of the efferent loop according to the method of Roux, with division of 1–2 jejunal vessels (if required). This made it possible to pull up the gastric stump into the left pleural cavity, and in some cases, even into the neck (!), and to perform the EGA on this level. The final stage of reconstruction is an end-to-side jejunojejunostomy (Roux-en-Y) anastomosis.

Over the last two decades, this variant of the gastric stump EP procedure has become widespread in China [29]. Many publications on the subject are available, including a large series of up to 15–20 cases [16, 32, 33]. Authors from Shantou presented the largest institutional series of 78 cases, with zero mortality [16]. This EP technique is considered by some surgical teams as the method of choice in gastrectomized patients [16, 34].

The technical details of the discussed EP method have been carefully developed, particularly by Chinese surgeons [16, 32–39]. The standard operative approach is a left thoracotomy or a left thoracoabdominal incision. If the tumour is resectable, the oesophagus is mobilized and the diaphragm is opened. The remnant stomach as well as the afferent and efferent loops of the jejunum are mobilized with the spleen and pancreatic tail. The ligaments of the spleen, followed by adhesions around the remnant stomach, are divided, and fixation in the mesocolic window (if present) is eliminated. The pancreatic tail is detached from the retroperitoneal fat. The left gastric vessels are divided, and the oesophagus is transected close to the cardia. The left gastroepiploic and short arteries remain the principal blood source for the gastric stump. It is necessary to save at least 2–3 short arteries [16, 38]. The remnant stomach after such mobilization can be pulled up to at least 20–25 cm. The efferent jejunal loop can be elongated by division of 1–2 jejunal vessels if needed. The afferent loop of the jejunum close to the gastrojejunal anastomosis (GJA) is cut, and the gastric end is closed. Then, the oesophagus is resected together with periesophageal fatty tissue and lymph nodes. The reconstructive stage of the procedure consists of EGA and Roux anastomosis.

It has been reported that the described technique for EP is relatively simple, not time-consuming, and requires only one incision and two (sometimes one) anastomoses. Postoperative complications are infrequent [16, 32, 36], and the mortality is zero in the majority of clinics [16, 18, 32, 36–38].

The experience of Chinese surgeons illustrates the feasibility of gastropancreaticojejunal (GSP) mobilization even in patients after a Billroth I gastrectomy. In such cases, the operation is supplemented with the extended Kocher’s manoeuvre. Principally, the EP after a Billroth II gastrectomy is technically much easier than after a Billroth I gastrectomy [35]. Therefore, the latter case is particularly rare [16, 18, 35, 40], and there are no reliable summary statistics on such surgeries. Decreasing the tension in the area of the EGA semicircular seromyotomy of the remnant stomach has been employed [41]. Later, this technique was adopted for thematic EP after Billroth II DGE [18, 32].

In our opinion, conversion of a reconstructive scheme from a Billroth I into a Roux-en-Y can be considered to be a valid solution in gastric stump EP. We have not found any carefully described examples of this conversion in the literature. However, this idea is so intuitive and logical that such clinical case reports cited by well-informed colleagues should not be considered unusual.

Data on the follow-up results of EP with GSP mobilization are scarce. The following rates of 5-year survival have been reported: 25.0 [42], 30.6 [16] and 36.3% [32], which do not vary significantly in comparison with non-gastrectomized oesophageal cancer patients [16] or gastrectomized patients after colonic EP [42].
However, the oncological validity of the discussed EP method remains unclear. In distal oesophageal cancer, the technical success of translocation of the GSP complex into the thoracic cavity for infra-aortic EGA is in conflict with the high likeliness of perigastric metastases on the minor curvature of the stomach. Theoretically, this can preclude the usage of the gastric stump for EP in favour of a remnant gastrectomy plus oesophageal replacement with the bowel segment, or a minor curve resection may be recommended before the reconstructive stage of the operation. Furthermore, adequate lymphadenectomy of the left paracardiac nodes (Group 2) during the EP was stated to be almost impossible due to the risk of injury to the short gastric vessels [42].

In general, the purely oncological aspects of the discussed type of EP are not well-characterized (e.g. the technique of abdominal lymphadenectomy or the pattern of cancer recurrence—with particular interest to non-removed mediastinal and perigastric lymph nodes), and this is a field for future investigations.

MOBILIZATION OF THE REMNANT STOMACH AFTER SPLENECTOMY

The difference between this method of remnant stomach mobilization and the former is the need for splenectomy instead of a splenic transposition with the gastric stump into the pleural cavity. The vessels of the spleen have to be divided as close as possible to the splenic hilus. This prevents an unlikely injury of the left gastroepiploic vessels. As it is necessary to pull up the remnant stomach to the higher level, it is possible to mobilize the pancreatic tail.

In 1953, Emerson [43] reported a case that can be considered exclusive, even today. The patient had previously undergone pancreateoduodenectomy for pancreatic head cancer and presented with metachronous oesophageal cancer. After high-level oesophageal resection, EP was successfully performed using the gastric tube with the left gastroepiploic artery as the only source of gastric circulation (because the right gastric and right gastroepiploic vessels were divided during the pancreatectoduodenectomy). To obtain the reconstruction, the surgeon removed the spleen and transposed pancreatic remnant (tail of the gland) and the jejunal loop, anastomosed with the stomach, into the thoracic cavity.

From the original article [43], the extent of the gastric resection, performed during prior pancreatectoduodenectomy, is not clear. We believe that it was a limited resection of the distal stomach. Nevertheless, this is probably the first case of remnant stomach EP.

A procedure involving gastric stump EP with splenectomy after subtotal DGE was first performed in our clinic. It was conducted by Valentina P. Kleshchevnikova, who was, at that time (1957), an Associate Professor of the Faculty Surgery Department at the Leningrad Pediatric Medical Institute (Fig. 1).

In 1937, the female patient had undergone DGE for distal gastric cancer. In 1957, at the age 60, she was operated on for lower third oesophageal cancer (Fig. 2A). The distal part of the oesophagus was resected, and the spleen was removed with the ‘intrahilar’ technique. The remnant stomach was mobilized, preserving the left gastric artery, which was not divided during the course of the prior gastrectomy. An EGA was constructed immediately under the aortic arch (Fig. 2B). The postoperative period was uncomplicated, and the patient was discharged in good condition and returned to work. She died 7 years and 5 months postoperatively due to a myocardial infarction (confirmed by autopsy).

This clinical case was presented in two publications: a dissertation by Kleshchevnikova [21] and a monograph published as a limited edition in a Russian province [24]. We describe this report carefully because it is, to the best of our knowledge, the first case of gastric stump EP after subtotal DGE in general. As the above-mentioned one (Rusanov’s method), this technique of EP was abandoned for many years after its first employment. In 1969, French surgeons used it in one case with good immediate results [44]. Two cases were described by Chinese surgeons. After division of the left gastric artery and mobilization of the pancreatic tail, it was possible to make an EGA in the bottom of the
pleural cavity [4]. Seven cases were published by another Chinese team [20]. Finally, in 2007, Takemura et al. [19] presented their report, which was significantly different from the primary cases with respect to the technical details. A staged EP following thoracoscopic oesophagectomy with division was described. A tubular gastric transplant was tailored after minor curve resection (for oncological reasons), and it was then transposed into a subcutaneous tunnel. In such a situation, it appears to be impossible to avoid splenectomy due to technical considerations.

The reviewed modification of EP had a single principal difference compared with the above-mentioned one, which is the removal of the spleen as opposed to its transposition into the pleural cavity. The main reason for the splenectomy is that it provides a radical solution to problems related to transferring the spleen into the thorax and its fixation therein. Cheng et al. [4] and Li et al. [20] report the same: ‘Our method not only preserves the short gastric and left gastroepiploic vessels, but also obviates the problem of having to translocate and stabilize the spleen in the pleural cavity to preserve blood supply to the gastric remnant. The disadvantage of this method is the removal of an immunologically important organ. Unfortunately, the small number of EP procedures that have been presented do not allow a definite evidence-based conclusion regarding which method of the two is the best in general.

Although this method is chronologically the first among the different gastric stump EP techniques, it is not the most popular compared with EP with GSP transposition into the pleural cavity.

**OESOPHAGOPLASTY USING THE REMNANT STOMACH FED FROM THE RIGHT GASTRIC AND THE RIGHT GASTROEPIPLOIC ARTERIES**

This possibility rarely exists because standard DGE is accompanied by division of the above-mentioned vessels. This technique is more suitable for EP, which is not performed after DGE, but simultaneously with it. Ono et al. [8] reported a small series of gastric EPs for oesophageal cancer using the stomach with an existing ulcer in its distal part. The authors performed a limited DGE and saved the right gastric and the right gastroepiploic vessels, with Roux-en-Y reconstruction, favoring the oesophageal replacement with the stomach. A similar reconstruction approach was used in a case presented by Ohno et al. [48] after one-stage oesophageal resection and DGE for simultaneous oesophageal and gastric cancers. Using the same technique, a team from Brazil successfully resected an oesophageal cancer and distal gastric lymphoma in an 82-year-old patient [49]. The same approach was used to perform the resection and reconstruction in combined peptic stenoses of the oesophagus and the postbulbar duodenum [50].

In his dissertation, the Russian surgeon Lishov [23] reported that in combined caustic stenoses of the oesophagus and distal stomach, it is wise to save the right gastric and the right gastroepiploic vessels during DGE in the first stage of surgical treatment. There may be further need for EP with the resected stomach because oesophageal stenosis develops later than gastric outlet obstruction. The author noted that this type of EP, with an original ‘supercharge’ of the remnant gastric transplant, was performed with good results in three cases. Unfortunately, the technical and tactical details of the method were not described explicitly.

**AN ANTIPERISTALTIC (REVERSED) GASTRIC TUBE TAILORED FROM THE MAJOR CURVE**

The Romanian surgeon Gavriliu, who was one of the first surgeons to perform EP using a reversed gastric tube (RGT) tailored from the major curve of the stomach, widely used his method even in patients who had undergone partial DGE for postburn pyloroduodenal stenosis or a peptic ulcer. To lengthen the transplant, he developed a new modification of RGT with inclusion of the first part of the duodenum (the so-called Gavriliu II procedure) [45]. By 1975, the author had performed 106 operations using the described technique after prior antroplasty [46].

It is possible to create the RGT simultaneously with pyloroantral resection. A type of surgical intervention was described by Skvortsov [22] (Irkutsk, Russia) in a patient with combined caustic stenosis of the oesophagus and the distal stomach. For pyloroantral stenosis, a limited DGE has been performed with tailoring of RGT and its subcutaneous transposition. As severe dysphagia occurred, RGT was opened and employed as a feeding stoma. Ten weeks after the DGE, a distal intrapleural EP using RGT was performed. The postoperative period was complicated, with leakage and then with stenosis of EGA. The results of subsequent surgical reconstruction of the anastomosis were good and stable for many years. A similar operation was successfully performed in two cases by the other Russian team [47]. In some instances, it is possible to create a narrow RGT after prior non-limited DGE. The main sources of gastric stump and RGT circulation are the left gastric and the left gastroepiploic arteries. In 2005, the successful use of this technique was reported in three cases; two were performed after Billroth II, and one was performed after Billroth I [4].

Colleagues from the other Chinese institution used this type of EP in 5 patients [20].

**OESOPHAGOPLASTY USING THE REMNANT STOMACH FED FROM THE LEFT GASTRIC AND SHORT GASTRIC ARTERIES**

As noted above, the left gastric vessels significantly limit the mobility of the gastric stump. This is the reason why these vessels should be divided in the course of remnant stomach EP. Only in rare cases with a large remaining stomach and a relatively low level of oesophageal resection (distal third) can the left gastric vessels be saved. In some cases, it may be sufficient to divide the abdominal oesophagus and/or any of the upper short gastric vessels. Otherwise, it is important to implement other methods of mobilization, such as to divide all of the short gastric vessels be saved. In some cases, it may be sufficient to divide the abdominal oesophagus and/or any of the upper short gastric vessels. Otherwise, it is important to implement other methods of mobilization, such as to divide all of the short gastric vessels [26], to perform a semicircular seromyotomy of the remnant stomach anterior wall [41], to mobilize the spleen and pancreatic tail [25] or to remove the spleen [21].

Based on our review of the literature, we conclude that this subtype of gastric stump EP has been used by different surgeons, but in single cases. The left gastric artery was usually saved, not as a single source of blood, but as the main of two sources to supply the EP [21, 25, 26, 41].

The majority of the thematic case observations were made 30–50 years ago. Today, surgeons rarely use this method. Four cases were reported by Wang et al. [51], three cases by Peng and Wang [38] and one case by Miao et al. [52]. It is noteworthy that the cited authors also use other methods of gastric stump EP. The following is a citation from a recent article:
‘For feeding of the remnant stomach, the left gastric and short gastric arteries were used; the direct anastomosis was created between the esophagus and gastric stump. According to the author’s experience, this method is simpler and more time-saving, than the other two ones (transposition of the spleen with pancreatic tail and full mobilization of the remnant stomach – Y.S.). Special attention should be paid to the relatively large size of the remnant stomach and absence of tension in the area of anastomosis. If substantial tension appeared, EP turned to GSP transposition into the left hemithorax with subsequent esophagogastrectomy, or esophageal reconstruction with the large bowel’ [52].

Currently, the division of the left gastric artery at its origin is a standard step in gastric EP in patients with an intact stomach. However, the history of esophageal surgery includes some attempts to preserve this vessel to improve the circulation in gastric transplant [21, 53]. Thus, Sweet wrote the following in one of his early works:

‘In all cases the ascending branches of the left gastric vessels must be severed to make it possible to swing the fundus far enough into the thorax to permit a high anastomosis. In some cases in which the growth is unusually high, so that the esophagus must be divided close to or even above the aortic arch, it is necessary to divide the left gastric artery close at its origin and to cut the left gastroepiploic artery. I have proved by actual performance that this can be done with a successful outcome’ [53].

However, the left gastric artery salvage was abandoned. In his later articles, even Sweet did not refer to this technical possibility, and the left gastric artery division was mentioned as the only possible step of the procedure. In 1960, Kleschevnikova noted the following:

‘There was a time when Professor S.V. Heinatz (her teacher, former Head of our Academic Department from 1948 to 1958 – Y.S.) proposed salvage of the left gastric artery to improve the gastric circulation. However, it was not always possible to pull-up the stomach into the pleural cavity for high EGA due to severe tension of the gastropancreatic ligament, sometimes with subsequent injury of the artery’ [54].

Moreover, salvage of the left gastric artery can challenge the lymph node dissection around the celiac trunk and along the minor curve, and it can therefore be considered to be an oncologically invalid method.

Nevertheless, a procedure involving left gastric pedicle salvage was recently successfully performed in esophagogastroplasty (EGP) for cicatricial stenoses of the esophagus. Shraer (Kemerovo, Russia) proposes intrathoracic oesophageal bypass for mid thoracic oesophageal stricture using the original technique of gastric transplant formation [55]. Gastric ligaments on both curves have to be divided, saving the left gastric pedicle, and the gastric conduit is pulled up into the right hemithorax via the hiatus, which is widened by the right crurotomy, with subsequent ‘side-to-side’ EGA. In this technique, the stomach is transferred into the thorax and fixed at the point of the left gastric pedicle as if it is being ‘rolled up’, which explains the proposed term, ‘EGA by the rollover method’. Fifteen successful operations have been performed by the author [55], and this method was later successfully used in the clinic [23].

In 2010, Okereke [56] presented a case using a similar EGP technique. However, he performed esophageal resection instead of bypass, creating an EGA immediately below the aygos vein arch. In this case, EGP was carried out using a stomach that had been resected 4 years earlier with a division of both right and left gastroepiploic arteries during gastrectomy.

The left gastric artery was the principal source of blood for the gastric conduit.

**OESOPHAGOPLASTY USING A COMPLETELY MOBILIZED REMNANT STOMACH**

This concept is described in an article by Dionigi et al. [17], where a highly unusual observation was presented. At the time of esophageal resection for cancer in a previously (38 years ago) gastrectomized patient, the remnant stomach was completely mobilized with transection of all of the supplying vessels. Surprisingly, the stomach remained viable, and its circulation was considered satisfactory as a result of blood inflow from the efferent jejunal loop through the GJA. The completely mobilized remnant stomach was used for EP, and an EGA was constructed on the level of the azygos vein. The postoperative course was uneventful.

This procedure is particularly impressive. In theory, this brilliant method seems to be impossible. I observed several remnant gastrectomies in the clinic when the remnant stomachs had turned blue and dusky after full mobilization. However, while reviewing the literature, I found that the described method has a short but unique history.

In 1974, Koga et al. (Japan) [57] presented a case of complete mobilization of a gastric stump following a Billroth I DGE. The stomach remained viable due to the blood inflow from the duodenal anastomosis of the gastrojejunal anastomosis. The EGA after resection for lower oesophageal cancer healed smoothly.

Zhang et al. (China) [59] have successfully performed a similar operation (cardiectomy of gastric stump with its full mobilization and EGA) for cancer of the gastric cardia following gastrectomy [58]. The authors investigated this procedure experimentally. Sixty dogs underwent DGE and were reoperated on 5 months later using the technique mentioned above with stapling EGA. The survival rate was quite high (37 of 46 dogs, 80.4%), and EGA leakage was observed in only three animals (6.5%). The authors show that blood supply of the remnant stomach is obtained by the inflow from an Anastomosed jejunal (duodenal) and vascular implantation of the omentum around the stoma. Thereafter, the same authors published their results of gastric stump cardiectomies performed in the clinic, and in 17 operated patients, no ischaemic complications of the gastric stump or EGA were found [60]. These observations are of fundamental importance to the topic discussed.

In the last two decades, several Chinese surgeons have used a fully mobilized gastric stump for EP for oesophageal (usually, lower third) cancer, as well for cardiac cancer, in patients after DGE.

Fu et al. [61] presented a series of five surgical cases after Billroth II DGE. Four of them recovered smoothly, and in one case, EGA leakage was observed and cured conservatively. Another Chinese team also reported five cases with good results [62]. The largest recent series consisted of 15 operations without fatal outcomes, 12 of which were for oesophageal cancer and 3 were for cardiac cancer after DGE [63]. Several authors have published reports involving 1–2 cases using this method not as a standard, but in particularly favourable situations [52, 64].

If the blood supply of a gastric stump after full mobilization was always reliable, this method of EP could be regarded as the method of choice after DGE. Unfortunately, this is not always the...
case. Zhang and Zhang [62] stated that ‘Quite good results of surgical treatment could be obtained in the following conditions: (1) not less than 10 years after gastrectomy, good collateral circulation in the area of GJA; (2) remnant stomach volume >300 ml; (3) after Billroth II procedure; (4) thorax is short in vertical dimension; (5) normal cardiopulmonary functions’.

Recently, we proposed an interventional radiological method, which can help to assess the viability of a completely mobilized gastric stump preoperatively [65]. There is a two-step endovascular procedure. After celiacography, the left gastric artery (if it was not divided in its origin in gastrectomy) was subjected to embolization. Then the splenic artery was occluded in its proximal part with a balloon catheter, and the gastric circulation measured by endoscopic Doppler flowmetry. In the absence of critical/subcritical ischaemia of the gastric stump, the success rate of the planned EP is substantial because the blockade of the main blood inflow to the stomach is compensated with capillary inflow through the GJA.

OESOPHAGOPLASTY USING THE REMNANT STOMACH WITH DIRECT REVASCULARIZATION

We found only one report relating to a procedure of this kind. Matsubara et al. [66] performed a splenectomy and mobilized the remnant stomach completely and then placed the gastric tube with the efferent jejunal loop preternally. Gastric circulation was restored by microvascular anastomoses between the remnants of the splenic vessels and large vessels on the neck. No complications occurred.

The next option, proposed by the author, will be noted, but has not yet been clinically introduced [67]. This is the direct revascularization of the left gastroepiploic vessels from the vessels of the efferent jejunum. The reconstructed left gastroepiploic artery is the main blood supply for the remnant stomach after its full mobilization.

DISCUSSION

Reasons for the employment of oesophagoplasty with the gastric remnant

The classical approach to EP in patients after DGE is the usage of the bowel segments. In the majority of clinics, colonic transplant is the preferred option [1–8]. Less frequently, jejunal EP is the method of choice [9–13]. In some institutions, both alternatives are employed widely [14, 15]. The discussion of the pros and cons of colonic and jejunal EP has a long history, and final conclusions have not been reached. This choice is, as a rule, not based on the DGE history itself. It is usually related to the positive and negative features of colonic/jejunal transplants as such, and to a considerable extent, it is guided by established institutional traditions. This problem is not discussed in this review. In large ‘oesophageal’ clinics, both types of bowel EP are skilfully performed and will give good results. The question is the following: what are the reasons for gastric stump EP use? The reasons appear to be different for different surgeons.

(i) Some surgeons use thematic EP as a version of standard gastric EP, adopting it based on the previous DGE. Here, it is possible to implement all of the advantages of gastric EP mentioned in the first paragraph of the article. It was clearly observed in the first remnant stomach EP. Let us briefly review a case report by Kleshevnikova [21]. The reconstruction method of choice must have been influenced by the clinical standards of EP as such. When our department was headed by Professor Sergey V. Heinatz (1948–58), a similar technique of gastric EP (with removal of the spleen) was also used in whole stomachs [24]. Intrahilar splenectomy was employed for improvement of the blood supply of the gastric fundus, which is the area of planned EGA. Kleshevnikova referred to this method as ‘gastric mobilization by Gavriliu’ [24], but this seems to be incorrect. In our clinic, an isoperistaltic gastric tube has been used instead of RGT based on Gavriliu’s experience.

Rusanov performed the procedure in the same way. He completed two unique gastric stump EP’s with splenopancreatic transposition [30, 31] by analogy with his original EP. This technique was successfully used in patients with intact stomachs [27, 28].

Gavriliu [45, 46] widely employed his method (RGT EP) even after pylorooantral resections that had been performed for cicatrical caustic stenosis or peptic ulcers. However, he adopted it especially for such cases, including insertion of the first part of the duodenum into RGT.

(ii) Forced inclusion of the remnant stomach into a reconstructive scheme for the purpose of performing any type of bowel EP is particularly difficult or impossible. Usually, the difficulty is related to the special features of mesenteric vascularization and/or the presence of severe scarring and adhesive processes. Thus, Lishov described the gastric remnant EP as a ‘non-standard’ approach and justified its use only when ‘standard’ bowel segments are unusable [23].

Matsubara et al. were forced to resort to revascularized remnant stomach EP due to severe and firm adhesions in the upper abdomen [66].

(iii) In some cases, gastric stump EP appeared to be used as a trial balloon. In case of failure, the surgeon can perform a bowel EP. It is impossible to refer to any specific example because procedure ‘planning’ of this sort is not discussed in the literature. However, it is important that the surgeon remains open to all options during the procedure. It is difficult to imagine that the first successful EP with a fully mobilized gastric stump had been planned preoperatively rather than improvised during the surgery. Many important ideas in numerous fields arise with no planning at all, reminiscent of the apple of Newton.

(iv) Some surgeons may consider the systematic use of a gastric stump EP after DGE as the method of choice. Currently, this approach has been applied in a number of Chinese clinics. This concept was founded by surgeons from Shantou, who rediscovered the EP with gastropancreatojejunal transposition [29]. Due to extensive clinical work, the surgical technique has been improved, and the range of its indications has been extended. In Shantou, the largest series of gastric stump EPs after non-limited DGE has been collected, including 78 cases with an absence of postoperative mortality [16]. A number of other Chinese clinics have a substantial number of cases and
excellent immediate results [32, 33, 37, 42]. Moreover, in some clinics, more than one thematic EP has been used along with the classic types of bowel EP after gastrectomy [4, 20, 33, 51, 68].

Oesophagoplasty with the gastric remnant: advantages, limitations and perspectives

The vast majority of the published cases of remnant stomach EP are restricted to the method of GSP transposition into the left hemithorax. Other techniques were employed much less frequently. Our aim is to describe the main advantages and disadvantages of a remnant stomach EP, which are primarily based on this common technique.

Among the benefits of this EP procedure is that it is a rather simple and low-invasive procedure; a left thoracotomy or thoracoabdominal approach is commonly used. Furthermore, the surgery is not time-consuming. According to Guo et al. [32], when using a stapling technique for EGA, it required 2.5–3 h. There are two anastomoses applied (EGA + jejunojejunal), but sometimes EGA alone is sufficient. This operation provides a high oncological radicalism and adequate surgical margins [32, 39]. EGP following DGE preserves the remnant stomach and its function, which enables a good functional result and a high quality of life for the patient [16, 18, 32, 36, 37]. Based on Chinese statistics, the rate of complications is low, accounting for 8.3–16.7% [16, 36, 37], and the mortality is usually zero [16, 18, 32, 36, 37, 42].

However, the reserves of the GSP complex mobilization are limited. It is not always possible to pull up the gastric stump into the pleural apex or to the neck. These cases are rare even in China [16, 20, 32]. This is why gastric stump EP in oesophageal lesion with high localization should be considered as exclusive cases.

From the technical point of view, this EP procedure is the easiest and safest in lower oesophageal cancer: resection with a sufficient surgical margin can be performed with subsequent EGA below the aortic arch. However, there is a lack of oncologic adequacy due to the high risk of involvement of the non-resected mediastinal and minor curve gastric lymph nodes. Moreover, resection of the left paracardiac lymph nodes (Group 2) appears to be quite difficult due to the risk of injury to the short gastric vessels [42].

The next important disadvantage of the discussed technique is its absolute dependence on the left thoracic or thoracoabdominal approach. Transposition of the GSP complex into the right hemithorax is prevented by excessive bending of the pancreas and biliary ducts, potentially causing pancreatitis and biliary obstruction. The risk of this deformity was shown experimentally almost half a century ago by Fedotkin in his thesis on EP using the stomach mobilized with the spleen and pancreatic tail [69]. There is a significant approach-dependent difficulty when accessing more proximal parts of the oesophagus and in lymph node dissection of the upper mediastinal region.

Almost all of the statements mentioned above also apply to the next method of thematic EP — gastric (or gastropancreatic) mobilization with splenectomy. Currently, there is no evidence regarding which technical method represents an option for EP regarding the thoracic transposition of the spleen or its removal. A transposed spleen has to be fixed to the thoracic wall with the splenic ligament remainders to prevent tension of the EGA and torsion of the splenic hilus [16, 18]. A splenic translocation into the oesophageal bed in the case of planned infra-aortic EGA was reported [32]. Correct and thorough use of these methods promoted satisfactory results. The vast majority of authors have not observed any complications due to placement of the spleen in the pleural cavity. However, some consider the placement of the spleen, tail and a portion of the body of the pancreas and efferent jejunum into the chest cavity to have a negative effect on breathing and the vital capacity of the lungs [70]. Some authors suggest that left-sided pneumonia and atelectasis can result from lung compression caused by the spleen [63, 64]. It is important to note that after GSP transposition, patients and their relatives should be informed about the type of surgery performed so that in the future, the repositioned spleen will not be mistaken for a tumour or lymph node conglomerate on an X-ray [71].

Surgeons from Nanjing employed both methods of thematic EP, performing the procedure with spleen transposition and its removal. They chose splenectomy when the spleen was ‘too large’ [20]. In our opinion, the use of unforced splenectomy for technical reasons cannot be justified. The real harm related to the removal of an important immunocompetent organ cannot be compensated with illusory benefits of resolving ‘the problem of having to translocate and stabilize the spleen in the pleural cavity’ [20].

The current state of reconstructive surgery of the oesophagus is characterized by refusal from the use of antiperistaltic gastric tubes, which accounts for a high percentage of anastomotic leakage and strictures of the oral part of the gastric tube. One of the most recent large series of RGT was published in 1978 based on paediatric material [72]. The authors reported the occurrence of EGA leakage in 63% of cases and stenosis in 43%; the presented series consists of 30 gastric tubes, and 27 of them were antiperistaltic. Currently, surgeons from the Russian Research Center for Surgery do not perform this type of EP due to the unreliable circulation in the oral part of the transplant and the high percentage of its inadequate length for retrosternal and subcutaneous placement, particularly in cases with prior gastrectomy [73]. The use of RGT tailored from the previously resected stomach had to be justified convincingly. As a rule, such a tube can only replace the distal oesophagus. However, for a distal EP, there are several better alternatives. The performance of EP using RGT after subtotal DGE is very limited and has been presented in two publications only. The operative technique is described very briefly [4, 20]. Therefore, this technique is the subject of further investigations.

EP with the gastric stump fed by the right gastric and right gastroepiploic arteries could be used exclusively in those cases when, in the process of DGE, the surgeon considers future oesophageal replacement. This may be possible only in cases of combined chemical burn of the oesophagus and distal stomach. It is important to maximally preserve the gastric vasculature during surgery for pyloric stenosis because the stomach is the potential plastic material to be used for EP. Lishov proposed a vessel-saving concept not only for gastroduodenostomy or pyloroplasty, but for DGE as well [23]. At the cost of some complication of the surgical technique, the remnant stomach was used later for EP without splenopancreatic mobilization, i.e. maximally close to the standard posterior mediastinal EP in a whole stomach. However, it is difficult to say whether this perspective is appropriate. The author notes that several such EPs were performed in the clinic, but important details of these operations remain unknown, such as the level of EGA and the time interval
between the DGE and EP. We believe that after DGE (especially Billroth I), the right gastroepiploic vessels, being mobilized but not divided, can significantly shrink with time and acquire curvature, which can prevent EP in such modification. Recently, responding to our request, Lishov reported that the discussed type of the gastric EP was used in 3 cases. There were intrapleural bypasses through the right thoracic approach. Time interval between DGE and EP was not <9–12 months. Shrinkage of the right gastroepiploic vessels was not observed (E.V. Lishov, personal communication). It is necessary to perform experimental and clinical works to improve this subtype of EP.

In our opinion, the above-mentioned vessel-sparing DGE technique can be helpful in antrectomy, combined with vagotomy and Roux-en-Y diversion for severe/complicated reflux oesophagitis. The original technique is accompanied by right gastric and right gastroepiploic vessels division [74]. However, in some cases, following the operation, oesophageal resection and reconstruction will be required due to the progression of peptic stricture. It seems that vessel-sparing antrectomy allows for the preservation of a gastric remnant EP, though as a second-line EP method, in such cases.

Saving the left gastric artery, which can almost guarantee prevention of ischaemic complications in the remnant stomach EP, cannot be used as a routine method. This vessel fixes the resected stomach, and maintaining the left vessels is only possible in some cases of distal EP. Second, saving the left gastric artery (LGA) seems to contradict oncological principles because it hinders an adequate lymphadenectomy in the area of the celiac trunk and minor curve. Therefore, the conditions justifying the preservation of the LGA in gastric remnant EP are limited to distal EP in benign oesophageal stenosis. Such operations are highly exclusive [22, 25, 56].

EP with a completely mobilized remnant stomach is a particularly interesting method. The transplant is a kind of jejunal with the addition of gastric build-up with no main blood supply. The gastric stump remains viable because of blood inflow from the efferent jejunum through the GJA. After division of 1–2 jejunal arteries, such a ‘combined’ substitute can be pulled up to a relatively high level. Importantly, this type of EP can be undertaken in a standard operative approach (laparotomy + right thoracotomy). Recently, Turkish colleagues wrote that before deciding to perform a jejunal or colonic transposition, the viability of the skeletonized remnant stomach should be evaluated; and if the blood supply of the stomach is adequate, oesophagastrectomy may be preferred to avoid potential complications of bowel transposition [75]. The main challenge of this method is how to predict the viability of the gastric stump after its complete mobilization. Our method of splenic artery balloon occlusion [65] can be helpful, but if it is technically unavailable, some ‘empiric’ recommendations can be used [62]. To perform successful EP, the most important criterion is the long time period between DGE and EP (not less than 10 years, better 20–30 years); then, the chances for success are substantial. However, this method of EP remains to be experimentally tested because the prior investigations [59, 60] do not show whether it is reliable in high-level (subtotal) oesophageal resection. Moreover, the discussed method of EP is of immediate interest for fundamental biomedical disciplines (anatomy, physiology, etc.) due to unique events related to organ functioning because of its blood supply from neighbouring organs through a newly developed capillary net.

The clinical practice of direct revascularization of a remnant stomach transplant is limited to a single case [66]. It is difficult to explain this fact. The current state of reconstructive microsurgery justifies the vascular supercharge in difficult EP cases, especially in cases of plastic deficiency or for saving other types of reconstruction. This is particularly true with a gastric remnant in the development of critical ischaemia of the transplant. The variants of vascular reconstruction can be different, including the original ones, taking into account the surgical settings.

**CONCLUSION**

The excellent plastic properties and rich vascularization of the stomach justify its use for EP, even after prior resection procedures. Moreover, several different types of gastric remnant EP exist. However, these methods are not equivalent: some have been used in single cases, while others have been used tens or hundreds times. The most tested method is the EP with thoracic transposition of the gastric stump *en bloc* with the spleen and pancreatic tail. This method was proposed and first performed in Russia, but it was mostly developed by Chinese surgeons. In some surgical clinics of China, it is considered to be the method of choice in middle and lower thoracic oesophageal cancer after DGE. Analysis of the available data allowed us to determine that the immediate results of this EP are excellent, and the long-term results are acceptable. We believe that this EP method is promising, especially for early cancer, and it should be considered in future investigations, including studies of the technique of abdominal lymph node dissection with more accurate follow-up control, particularly regarding the time and location of cancer recurrence as well as a more strict definition of the indications. The other types of gastric stump EP are less developed but should be considered in future research. EP with a fully mobilized remnant stomach appears to be particularly promising regarding its practical (EP as such) and fundamental aspects. Finally, direct revascularization of remnant stomach transplant, which is practically not developed, can preserve the planned ‘conventional’ gastric stump EP in the case of severe ischaemia.

However, we believe that a poorly based extension of the indications for gastric stump EP is not suggested. Different methods of bowel EP should be considered as first-line methods of oesophageal replacement after prior gastrectomy. Nevertheless, in difficult surgical settings (severe adhesions, lack of ‘plastic reserve organs’ [23]), the possibility of performing a remnant stomach EP should be accepted.

Gastric stump EP cannot be considered as a standard procedure for oesophageal cancer. Limited mobilization reserve does not permit the use of the resected stomach for EP after subtotal oesophageal resection, regardless of the reconstruction method. Planning the remnant stomach for the EP, the surgeon inevitably limits the extent of oesophageal resection and, most important, the extent of the lymphadenectomy. Furthermore, several gastric stump EP subtypes are unusable in the standard surgical approach (laparotomy + right thoracotomy), and calls for a left-sided incision. Theoretically, it is more logical to use the remnant stomach EP for benign oesophageal stenosis but not cancer, because the limited oesophagectomy for benign cases is more justified.

It is interesting and important that the majority of the thematic EP methods have been proposed and implemented in Western Europe and Asian countries (Russia, Romania, China and Japan). Consequently, a considerable part of the relevant literature is non-English, and few of these papers have been
pursued as English versions. Therefore, the reference list for this ‘state of the art review’ is unusual in that less than half of the references are in English. The research may be improved by including a consideration of the multilingual literature. In addition, there is a substantial risk of missing some relevant references, and the author trusts that the readers will regard any potential inaccuracies or incomplete coverage of the problem with understanding.

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