Cureus
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Open Access Technical Report

A Proposed Embryology-Driven Tokuhara-Roux-en-Y-I and -II Classification Regarding Lifted Jejunum Location Following Total Gastrectomy

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Review began 10/28/2026
Review ended 11/08/2026
Published 11/14/2026

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DOI: 10.7759/cureus.119662

Abstract

Intraoperative reanastomosis and postoperative reoperation due to lifted jejunal twisting during Roux-en-Y (RY) reconstruction following total gastrectomy (TG) can lead to surgical complications. To address this surgical blind spot, we propose a novel classification based on midgut embryology to standardize RY reconstruction following TG. First, we highlight that the midgut cranial limb exhibits a single-turn helical structure with the superior mesenteric artery (SMA) as its axis, and it can be anatomically divided into two distinct portions, where its physiological ventral mesenteric surface corresponds to either the left or right surface of the primitive dorsal mesentery. Second, based on the ventral mesenteric surface of the proximal lifted jejunum during the esophagojejunostomy, we establish a new classification for RY reconstruction following TG, designated as the Tokuhara-RY-I (T-RY-I) and Tokuhara-RY-II (T-RY-II) methods. The anal side of the lifted jejunum is positioned on the patient's right side in the T-RY-**I** method, and on the patient's left side in the T-RY-II method. Third, we introduce the reconstruction procedures for establishing the T-RY-I and T-RY-II methods following TG, while identifying the procedures where twisting of the lifted jejunum is likely to occur. In conclusion, to reliably prevent lifted jejunal twisting in RY reconstruction following TG, it is highly advisable to select the T-RY-II method. This selection is proposed as a strategy to ensure that the proximal lifted jejunum is systematically transitioned into its embryologically predetermined position, because the abdominal esophageal stump is located on the left side of the SMA. Otherwise, because it is considered that proximal lifted jejunal twisting in the T-RY-**I** method following TG can be prevented universally only when the anal side of the lifted jejunum is positioned at the patient's right side during the esophagojejunostomy and the esophagojejunostomy is located on the transverse plane, this method may carry a potential risk of lifted jejunal twisting without meeting these specific conditions. By incorporating this novel, embryology-driven classification and executing the corresponding standardized procedures following TG, surgeons may optimize anatomical reconstruction, enhance procedural safety, and effectively mitigate the risk of postoperative complications, although this proposed classification warrants further clinical validation.

Categories: General Surgery, Anatomy, Gastroenterology
Keywords: embryology, lifted jejunal twisting, midgut, roux-en-y reconstruction, total gastrectomy

Introduction

Roux-en-Y (RY) reconstruction, originally developed by César Roux, was first performed in 1892 for the treatment of gastric outlet obstruction [1]. In his original procedure, the jejunum was divided approximately 15-30 cm distal to the ligament of Treitz; a side-to-end anastomosis was then fashioned between the stomach and the distal jejunal segment, followed by a side-to-end jejunojejunostomy constructed roughly 12 cm distal to the gastrojejunostomy [1]. Although Roux performed this reconstruction in 116 patients, he ultimately abandoned the technique in 1911 due to a high incidence of marginal ulcers at the gastrojejunostomy [1]. Consequently, RY reconstruction fell into disuse during the first half of the 20th century [1]. However, animal experiments conducted in 1949 and 1956 demonstrated that regurgitation of intestinal contents could be effectively prevented when the length of the Roux limb was maintained at 30-60 cm [2,3]. Driven by these findings, RY reconstruction with a 40-45 cm Roux limb began to be widely adopted across various gastrointestinal surgeries in the 1950s [1].

To date, diverse procedures for RY reconstruction have been utilized following total gastrectomy (TG) [3-19]. Despite its widespread use, the procedure carries an inherent risk of anatomical misalignment. Specifically, three cases of intraoperative twisting of the lifted jejunum requiring immediate reanastomosis have been reported during laparoscopic TG [15,17]. Furthermore, a case of postoperative twisting of the lifted jejunum requiring reoperation following laparoscopic TG has also been documented [19]. Generally, these mechanical events may lead to postoperative complications and prolonged hospitalization.

To address this surgical blind spot, the present technical report proposes a novel embryology-driven classification to optimize RY reconstruction following TG. In the technical report section, first, we highlight that the midgut cranial limb exhibits a single-turn helical structure with the superior mesenteric artery (SMA) as its axis, and it can be anatomically divided into two distinct portions, where its physiological

ventral mesenteric surface corresponds to either the left or right surface of the primitive dorsal mesentery. Second, considering that the lifted jejunum in RY reconstruction originates from the midgut cranial limb, we propose a novel classification system termed the Tokuhara-RY-I (T-RY-I) and Tokuhara-RY-II (T-RY-II) methods, which are determined by the ventral mesenteric surfaces of the proximal lifted jejunum during the esophagojejunostomy, and further delineate the anatomical conditions required to establish both the T-RY-I and T-RY-II methods in gastrointestinal surgery. In the discussion section, we introduce the reconstruction procedures for establishing the T-RY-I and T-RY-II methods following TG, while identifying the procedures where twisting of the lifted jejunum is likely to occur. In the conclusion section, we propose a standardized surgical policy that may effectively prevent lifted jejunal twisting during RY reconstruction following TG.

Technical Report

Division of the midgut cranial limb into two portions with the SMA as the boundary based on midgut embryology

The midgut initially forms a ventral U-shaped loop, known as the midgut loop of the intestine, which is suspended from the posterior abdominal wall by the primitive dorsal mesentery [20]. This loop is anatomically divided into a cranial limb and a caudal limb, with the SMA serving as the central axis (Figure *1A*) [20]. The cranial limb subsequently differentiates into the distal duodenum, jejunum, and proximal ileum, whereas the caudal limb gives rise to the distal ileum, cecum, appendix, ascending colon, and proximal two-thirds of the transverse colon. During embryonic development, the midgut loop undergoes an initial 90-degree counterclockwise rotation around the SMA axis; consequently, the cranial limb shifts downward to the right side, while the caudal limb moves upward to the left side (Figure *1B*) [20]. Subsequently, the portion of the midgut loop distal to the inferior pancreaticoduodenal artery rotates two consecutive 90 degrees counterclockwise rotations. This secondary rotation drives the jejunum and proximal ileum posterior to the SMA and toward the left side, while displacing the distal ileum, cecum, appendix, ascending colon, and transverse colon anterior to the SMA and toward the right side (Figures *1C*-*1D*) [20]. Following these rotational shifts, the duodenum, cecum, and ascending colon become fixed to the retroperitoneum [20]. Conversely, the jejunum and ileum remain suspended from the retroperitoneum by the definitive mesentery, which extends diagonally from the duodenojejunal junction to the ileocecal junction [20].

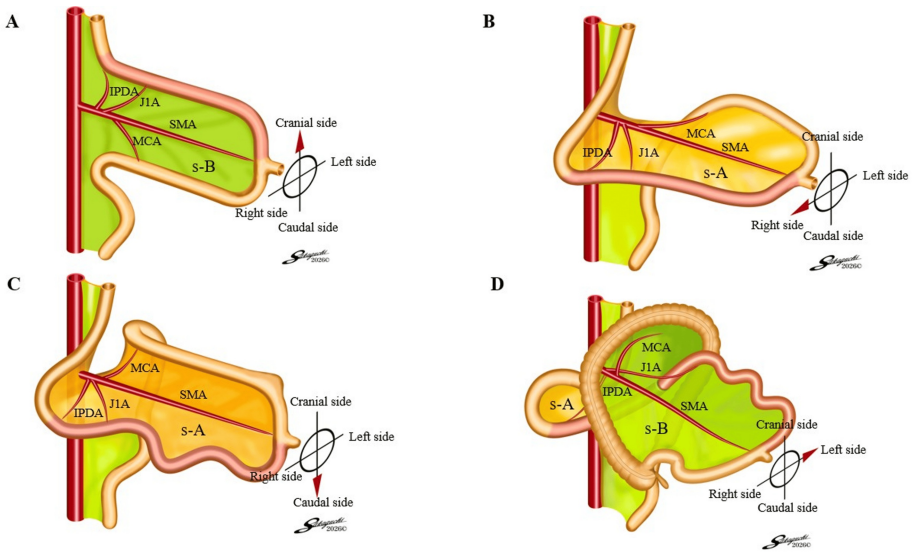


FIGURE 1: Midgut embryology

s-A: surface-A; s-B: surface-B; IPDA: inferior pancreaticoduodenal artery; J1A: first jejunal artery; MCA: middle colic artery; SMA: superior mesenteric artery

The left and right surfaces of the primitive dorsal mesentery are defined as s-A and s-B, respectively. (A) The midgut loop is divided into a cranial limb (brown) and a caudal limb by the SMA. The right surface of the primitive mesentery is s-B (green). (B) The midgut loop rotates 90 degrees counterclockwise, and the cranial limb (brown) moves to the right. The left surface of the primitive mesentery is s-A (yellow). (C) The midgut loop distal to the IPDA rotates 90 degrees counterclockwise, and the distal duodenum, jejunum, and proximal ileum move posterior to the SMA. (D) The midgut loop distal to the IPDA rotates an additional 90 degrees counterclockwise, and the jejunum and proximal ileum move to the left side. Figure 1 is presented as an anterior and three-dimensional schematic view, with orientation markers indicating the cranial/caudal and left/right axes from the viewer's perspective. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

Integrating this precise embryological process, we highlight that the midgut cranial limb exhibits a distinct

single-turn helical structure centered around the SMA axis. Accordingly, by defining the left and right surfaces of the primitive dorsal mesentery as surface-A (s-A) and surface-B (s-B), respectively (Figures *1A*-*1B*), the midgut cranial limb can be conceptually categorized into two discrete portions: (1) the segment located on the right side of the SMA, where its physiological ventral mesenteric surface corresponds to s-A, and (2) the segment located on the left side of the SMA, where its physiological ventral mesenteric surface corresponds to s-B (Figure *2*).

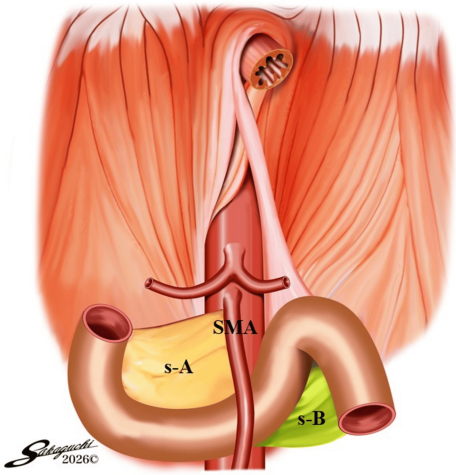


FIGURE 2: The cranial limb of the midgut

s-A: surface-A; s-B: surface-B; SMA: superior mesenteric artery

The left and right surfaces of the primitive dorsal mesentery are defined as s-A and s-B, respectively. The cranial limb (brown) exhibits a single-turn helical structure and consists of the portion on the right side of the SMA, with its physiological ventral surface being s-A (yellow), and the portion on the left side of the SMA, with its physiological ventral surface being s-B (green). The abdominal esophageal stump is positioned close to the SMA and is located on the left side of the SMA. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

The T-RY classification: concepts and rationale

RY reconstruction fundamentally consists of four sequential steps: (1) division of the marginal vessels or mesenteric arterial arcades to gain sufficient length of the lifted jejunum, (2) division of the jejunum, (3) anastomosis of the proximal lifted jejunum to the upper abdominal target organ, and (4) jejunojejunostomy constructed between the proximal jejunal segment and the proximal lifted jejunum. Because the lifted jejunum originates from the embryonic midgut cranial limb and maintains anatomical continuity with the ileum, its physiological ventral mesenteric surfaces are predetermined by its spatial relationship to the SMA axis. Specifically, the physiological ventral mesenteric surface of the lifted jejunum corresponds to s-A when located on the right side of the SMA and to s-B when located on the left side of the SMA. Based on these embryological constraints, we propose a novel classification system for RY reconstruction. We define the T-RY-I method as an RY reconstruction in which the ventral mesenteric surface of the proximal lifted jejunum during the esophagojejunostomy is oriented as s-A. Conversely, we define the T-RY-II method as an RY reconstruction in which the ventral mesenteric surface of the proximal lifted jejunum during the esophagojejunostomy is oriented as s-B. Structurally, the lifted jejunum exhibits a distinct single-turn helical structure under the T-RY-I method, whereas it assumes a linear structure under the T-RY-II method (Figures *3A*-*3B*). In the operation, the T-RY-**I** and T-RY-**II** methods are clearly defined based on the placement of the lifted jejunum during the esophagojejunostomy: it is designated as the T-RY-I when the anal side of the lifted jejunum is positioned on the patient's right side, whereas it is designated as the T-RY-II when the anal side is positioned on the patient's left side.

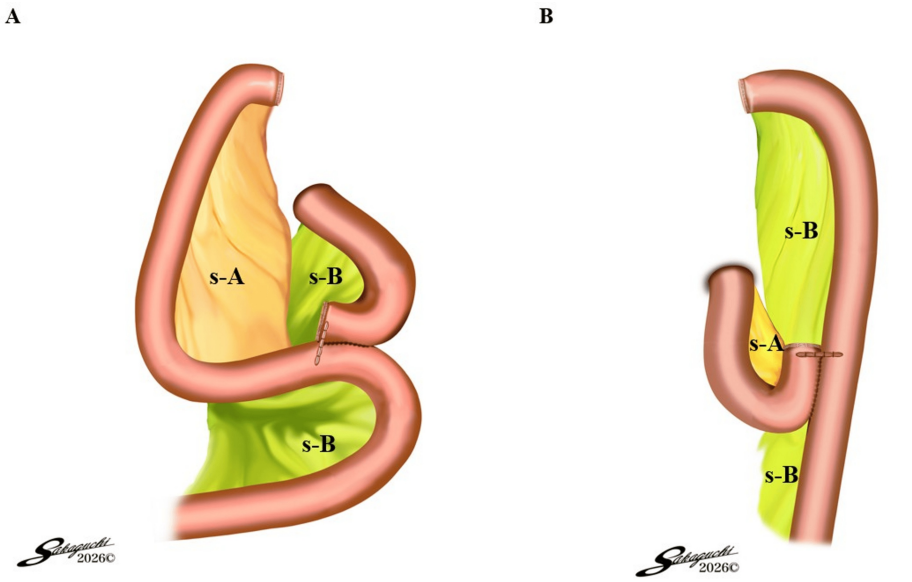


FIGURE 3: A new classification for RY reconstruction: T-RY-I and T-RY-II classification

s-A: surface-A; s-B: surface-B; RY: Roux-en-Y; T-RY-I: Tokuhara-RY-I; T-RY-II: Tokuhara-RY-II

The left and right surfaces of the primitive dorsal mesentery are defined as s-A and s-B, respectively. (A) RY reconstruction with its ventral mesenteric surface of the proximal lifted jejunum during the esophagojejunostomy being s-A (yellow) is defined as the T-RY-I method. The lifted jejunum exhibits a single-turn helical structure. The anal side of the lifted jejunum is positioned on the patient's right side. (B) RY reconstruction with its ventral mesenteric surface of the proximal lifted jejunum during the esophagojeunostomy being s-B (green) is defined as the T-RY-II method. The lifted jejunum exhibits a linear structure. The anal side is positioned on the patient's left side. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

Conditions for establishing the T-RY-I and T-RY-II methods in gastrointestinal surgery

To successfully implement the proposed classification and ensure surgical safety, specific conditions must be fulfilled to establish the T-RY-I and T-RY-II methods in gastrointestinal surgery. First, during the anastomosis of the proximal lifted jejunum to the upper abdominal target organ, the proximal lifted jejunum must be spatially oriented such that its ventral mesenteric surface corresponds strictly to s-A without any twisting for theT-RY-I method or to s-B without any twisting for the T-RY-II method. Second, following the completion of this initial anastomosis, no secondary twisting or mechanical torsion of the lifted jejunum occurs.

Discussion

Procedures for establishing the T-RY-I method following TG

T-RY-I Method With Handsewn Esophagojejunostomy Following Open and Laparoscopic TG

In this T-RY-I method, the esophagojejunostomy, in which the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum with its ventral mesenteric surface being s-A are anastomosed, is performed by the handsewn technique. Moreover, because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-A with no twisting (Figure *4*); however, this proximal jejunal location is nonphysiological because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*). In addition, no twisting of the lifted jejunum can occur when the proximal lifted jejunum moves such that its ventral mesenteric surface is physiological s-B after the esophagojejunostomy because the esophagojejunostomy is located on the transverse plane. Thus, this T-RY-I method is considered to be established [3-6].

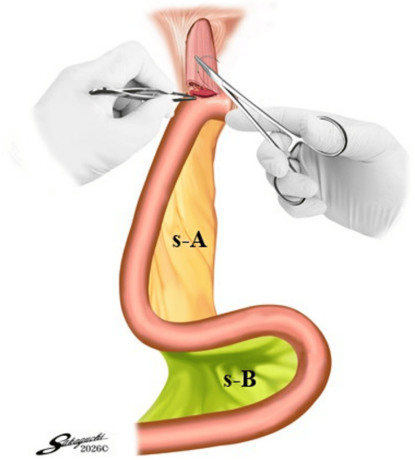


FIGURE 4: T-RY-I method with handsewn esophagojejunostomy following open TG

s-A: surface-A; RY: Roux-en-Y; T-RY-I: Tokuhara-RY-I; TG: total gastrectomy

After the proximal jejunum is located with its ventral mesenteric surface being s-A (yellow), the esophagojejunostomy is performed by the hand-sewn technique. During the esophagojejunostomy, the proximal lifted jejunum is located such that its ventral mesenteric surface is s-A (yellow), with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

T-RY-I Method With Circular-Stapled Esophagojejunostomy Following Open TG

In this T-RY-I reconstruction, after the circular stapler (CS) shaft is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-A from the oral to anal side, the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed. The esophagojejunostomy is completed by transecting the jejunal stump with the linear stapler (LS).

In open surgery, the insertion site of the CS shaft into the abdominal cavity can be freely selected, and the abdominal space to the left side of the esophageal stump for passing of the CS shaft is secured. Thus, both the direction of the CS shaft in the proximal lifted jejunum and that in the abdominal cavity are from left to right. Moreover, because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-A with no twisting (Figure *5*); however, this proximal lifted jejunal position is also nonphysiological because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*). Further, no twisting of the proximal lifted jejunum can occur when the lifted jejunum moves such that its ventral mesenteric surface is physiological s-B after the esophagojejunostomy because the esophagojejunostomy is located on the transverse plane. Thus, this T-RY-**I**method is considered to be established [7,8].

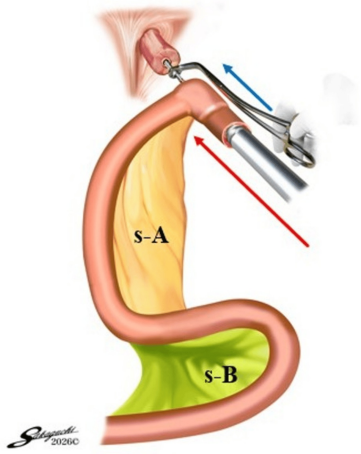


FIGURE 5: T-RY-I method with circular-stapled esophagojejunostomy following open TG

s-A: surface-A; RY: Roux-en-Y; T-RY-I: Tokuhara-RY-I; TG: total gastrectomy

Both the direction of the circular stapler shaft in the proximal lifted jejunum and that in the abdominal cavity are from the left to the right side (blue arrow, red arrow). During the esophagojejunostomy, the proximal lifted jejunum is located such that its ventral mesenteric surface is s-A (yellow), with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

Procedures for establishing the T-RY-II method following TG

T-RY-II Method With Handsewn Esophagojejunostomy Following Open TG

In this T-RY-II method, the esophagojejunostomy, in which the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum with its ventral mesenteric surface being s-B are anastomosed, is performed by the handsewn technique. Moreover, because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B with no twisting (Figure *6*). Further, because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) and this proximal lifted jejunal position is physiological, no twisting of the proximal lifted jejunum can occur after the esophagojejunostomy. Thus, this T-RY-II method is considered to be established [9].



FIGURE 6: T-RY-II method with handsewn esophagojejunostomy following open TG

s-B: surface-B; RY: Roux-en-Y; T-RY-II: Tokuhara-RY-II; TG: total gastrectomy

After the proximal jejunum is located with its ventral mesenteric surface being s-B (green), the esophagojejunostomy is performed by the hand-sewn technique. During the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B (green) with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

T-RY-II Method With Circular-Stapled Esophagojejunostomy Following Open TG

In this T-RY-II method, after the CS shaft is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-B from the oral to anal side, the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed. The esophagojejunostomy is completed by transecting the jejunal stump with the LS.

In open surgery, the insertion site of the CS shaft into the abdominal cavity can be freely selected, and the abdominal space to the right side of the esophageal stump for CS shaft passage is secured. Thus, both the direction of the CS shaft in the proximal lifted jejunum and that in the abdominal cavity are from right to left. Moreover, because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B with no twisting (Figure *7*). Because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) and this proximal lifted jejunal position is physiological, no twisting of the proximal lifted jejunum can occur after the esophagojejunostomy. Thus, this T-RY-II method is considered to be established [10,11].

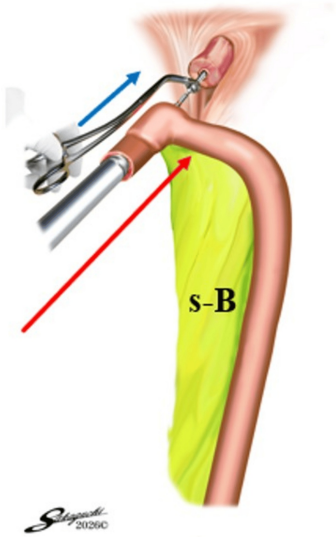


FIGURE 7: T-RY-II method with circular-stapled esophagojejunostomy following open TG

s-B: surface-B; RY: Roux-en-Y; T-RY-II: Tokuhara-RY-II; TG: total gastrectomy

Both the direction of the circular stapler shaft in the proximal lifted jejunum and that in the abdominal cavity are from right to left(blue arrow, red arrow). During the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B (green), with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

T-RY-II Method With Intracorporeal Circular-Stapled Esophagojejunostomy Following Laparoscopic TG

In this T-RY-II reconstruction, the jejunum is pulled out with its ventral mesenteric surface being s-B through a minilaparotomy at the umbilicus and divided. After the CS shaft is inserted into the proximal lifted jejunum from the oral to anal side and introduced into the abdominal cavity, the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by transecting the jejunal stump with the LS.

Because the jejunum is pulled out with its ventral mesenteric surface being s-B through the minilaparotomy at the umbilicus, the direction of the CS shaft in the proximal lifted jejunum is from the right to the left side. Moreover, because the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the CS shaft in the abdominal cavity is from the right to the left side and thus is the same as that in the proximal lifted jejunum. Because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B with no twisting (Figure *8*). As the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) and this proximal lifted jejunal position is physiological, no twisting of the proximal lifted jejunum can occur after the esophagojejunostomy. Thus, this T-RY-II method is considered to be established [12,13].

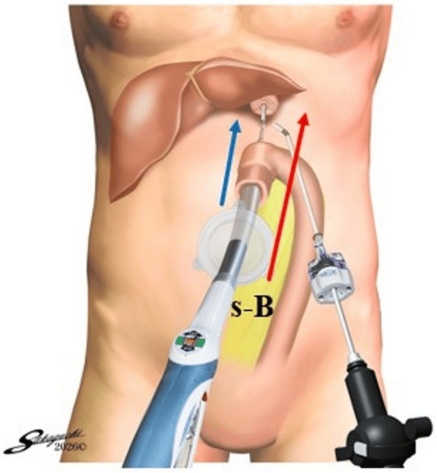


FIGURE 8: T-RY-II method with intracorporeal circular-stapled esophagojejunostomy following laparoscopic TG

s-B: surface-B; RY: Roux-en-Y; T-RY-II: Tokuhara-RY-II; TG: total gastrectomy

Both the direction of the circular stapler shaft in the proximal lifted jejunum and that in the abdominal cavity are from the right to left side (blue arrow, red arrow). During the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B (green) with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

T-RY-II Method With Linear-Stapled Esophagojejunostomy Using Functional End-To-End Anastomosis Following Laparoscopic TG

In this T-RY-II reconstruction, after the LS introduced from the left lower port is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-B from the oral to anal side, the left wall of the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by closing the entry hole with the LS.

Because the LS is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-B from the oral to anal side, the direction of the LS in the proximal lifted jejunum is from the right to left side. Moreover, because the left wall of the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the LS in the abdominal cavity is from the right to the left side and thus is the same as that in the proximal lifted jejunum. Because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B with no twisting. As well, because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) and this proximal lifted jejunal position is physiological, no twisting of the proximal lifted jejunum can occur after the esophagojejunostomy. Thus, this T-RY-II method is considered to be established [14,15].

T-RY-II Method With Linear-Stapled Esophagojejunostomy Using the Overlap Method Following Laparoscopic TG

In this T-RY-II method, after the LS introduced from the left lower port is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-B from the anal to oral side, the right or posterior wall of the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by closing the entry hole using the hand-sewn technique.

Because the LS is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-B from the anal to oral side, the direction of the LS in the proximal lifted jejunum is from the caudal to cranial side. Moreover, as the right wall of the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the LS in the abdominal cavity is from the caudal to cranial side and thus is the same as that in the proximal lifted jejunum. Because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B with no twisting (Figure *9*). Because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) and this proximal lifted jejunal position is physiological, no twisting of the proximal lifted jejunum can occur after the esophagojejunostomy. Thus, this T-RY-II method is considered to be established [16].

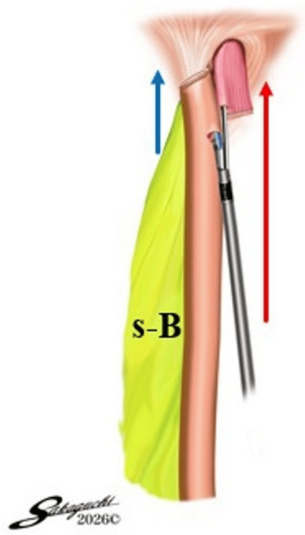


FIGURE 9: T-RY-II method with linear-stapled esophagojejunostomy using the overlap method following laparoscopic TG

s-B: surface-B; RY: Roux-en-Y; T-RY-II: Tokuhara-RY-II; TG: total gastrectomy

Both the direction of the linear stapler in the proximal lifted jejunum and that in the abdominal cavity are from the caudal to cranial side (blue arrow, red arrow). During the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-B (green), with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

T-RY methods potentially causing severe lifted jejunal twisting following TG

T-RY-I Method With Intracorporeal Circular-Stapled Esophagojejunostomy Following Laparoscopic TG

In this T-RY-**I**method, the jejunum is pulled out with its ventral mesenteric surface being s-A through a minilaparotomy at the umbilicus and divided. After the CS shaft is inserted into the proximal lifted jejunum from the oral to anal side and introduced into the abdominal cavity, the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by transecting the jejunal stump with the LS.

Because the jejunum is pulled out with its ventral mesenteric surface being s-A through the minilaparotomy at the umbilicus, the direction of the CS shaft in the proximal lifted jejunum is from the left to the right side. However, as the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the CS shaft in the abdominal cavity is from the right to the left side and thus is different from that in the proximal lifted jejunum. During the esophagojejunostomy, the proximal lifted jejunum might be located with its ventral mesenteric surface being s-B instead of s-A, potentially causing twisting. Therefore, twisting of the proximal lifted jejunum during the esophagojejunostomy can occur with this T-RY-**I** method. Indeed, such a procedural blind spot is clinically relevant; one case of intraoperative lifted jejunal twisting that necessitated immediate reanastomosis has been reported utilizing this approach [17].

T-RY-I Method With Linear-Stapled Esophagojejunostomy Using Functional End-To-End Anastomosis Following Laparoscopic TG

In this T-RY-**I** method, after the LS introduced from the left lower port is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-A from the oral to anal side, the left wall of the abdominal esophageal stump and the antimesenteric site of the lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by closing the entry hole with the LS.

Because the LS is inserted into the proximal lifted jejunum with its ventral surface being s-A from the oral to anal side, the direction of the LS in the proximal lifted jejunum is from the left to right side. However, because the left wall of the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the LS in the abdominal cavity is from the right to left side and thus is different from that in the proximal lifted jejunum. During the esophagojejunostomy, the proximal lifted jejunum might be located with its ventral mesenteric surface being s-B instead of s-A, and it can potentially twist. Therefore, twisting

of the lifted jejunum during the esophagojejunostomy can occur with this T-RY-**I** method. Indeed, such a procedural blind spot is clinically relevant; one case of intraoperative lifted jejunal twisting that necessitated immediate reanastomosis has been reported utilizing this approach [15].

T-RY-I Method With Linear-Stapled Esophagojejunostomy Using the Overlap Method Following Laparoscopic TG

In this T-RY-**I** method, after the LS introduced from the left lower port is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-A from the anal to oral side, the left wall of the abdominal esophageal stump and the antimesenteric site of the proximal lifted jejunum are anastomosed intracorporeally. The esophagojejunostomy is completed by closing the entry hole using the hand-sewn technique.

Because the LS is inserted into the proximal lifted jejunum with its ventral mesenteric surface being s-A from the anal to oral side, the direction of the LS in the proximal lifted jejunum is from the caudal to cranial side. Moreover, as the left wall of the abdominal esophageal stump is positioned in the left upper abdominal cavity, the direction of the LS in the abdominal cavity is from the caudal to cranial side and thus is the same as that in the proximal lifted jejunum. Because the abdominal esophageal stump is positioned close to the SMA (Figure *2*), during the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-A with no twisting (Figure *10*), although this proximal jejunal location is nonphysiological because the abdominal esophageal stump is located on the left side of the SMA (Figure *2*) [15,18,19]. However, because the esophagojejunostomy is located on the sagittal plane, the proximal lifted jejunum can twist when it moves such that its ventral mesenteric surface becomes physiological s-B after the esophagojejunostomy. Thus, twisting of the proximal lifted jejunum after the esophagojejunostomy can occur with this T-RY-**I** method.

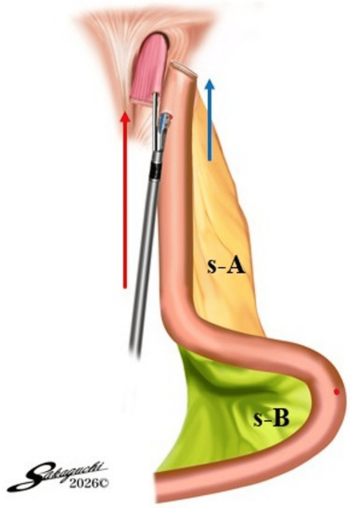


FIGURE 10: T-RY-I method with linear-stapled esophagojejunostomy using the overlap method following laparoscopic TG

s-A: surface-A; RY: Roux-en-Y; T-RY-I: TG: total gastrectomy

Both the direction of the linear stapler in the proximal lifted jejunum and that in the abdominal cavity are from the caudal to cranial side (blue arrow, red arrow). During the esophagojejunostomy, the proximal lifted jejunum can be located such that its ventral mesenteric surface is s-A (yellow), with no twisting. Image credit: Original illustration created by Shigeyuki Sakaguchi for this study

Indeed, one case of postoperative lifted jejunal twisting that required reoperation has been documented using this technique [19]. In the first operation, the proximal lifted jejunum was located such that its ventral mesenteric surface was s-A. At two months postoperatively, the patient presented with frequent vomiting, and upper gastrointestinal endoscopy and fluoroscopy revealed the stenosis of the proximal lifted jejunum due to its twisting and the blind pouch dilation. Because sufficient oral intake was not ensured with conservative treatment, reoperation was performed at five months postoperatively. The twisted proximal lifted jejunum with its ventral mesenteric surface being s-B was adherent to the diaphragmatic crus. Adhesiolysis, T-tube stent placement at the proximal lifted jejunum including the esophagojejunostomy, and resection of the dilated blind pouch were performed. The postoperative course was favorable, and oral intake was resumed. Otherwise, some authors have reported anchoring the proximal lifted jejunum to the duodenal stump with several tactical stitches to prevent its movement [15,18].

Conclusions

In TG with RY reconstruction, intraoperative reanastomosis and reoperation necessitated by lifted jejunal twisting can represent postoperative complications that prolong hospitalization. In conclusion, to prevent lifted jejunal twisting in RY reconstruction following TG, it is highly advisable to select the T-RY-II method. This selection is proposed as a novel strategy to ensure that the proximal lifted jejunum is systematically transitioned into its embryologically predetermined position, because the abdominal esophageal stump is located on the left side of the SMA. Otherwise, because it is considered that proximal lifted jejunal twisting in the T-RY-**I** method can be prevented universally only when its ventral mesenteric surface during the esophagojejunostomy is s-A, the anal side of the lifted jejunum is positioned on the patient's right side during the esophagojejunostomy, and the esophagojejunostomy is located on the transverse plane, this method may carry a potential risk of lifted jejunal twisting without meeting these specific conditions. By incorporating this novel, embryology-driven classification and executing the corresponding standardized procedures following TG, surgeons may optimize anatomical reconstruction, enhance procedural safety, and effectively mitigate the risk of postoperative complications, although this proposed classification warrants further clinical validation.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Takaya Tokuhara

Drafting of the manuscript: Takaya Tokuhara

Critical review of the manuscript for important intellectual content: Takaya Tokuhara

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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