

# European perspective in Thoracic surgery – eso-coloplasty: when and how?

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**Abstract:** Colon interposition has been used since the beginning of the 20<sup>th</sup> century as a substitute for esophageal replacement. Colon interposition is mainly chosen as a second line treatment when the stomach cannot be used, when the stomach has to be resected for oncological or technical reasons, or when the stomach is deliberately kept intact for benign diseases in young patients with long-life expectancy. During the surgery the vascularization of the colon must be carefully assessed, as well as the type of the graft (right or left colon), the length of the graft, the surgical approach and the route of the reconstruction. Early complications such as graft necrosis or anastomotic leaks, and late complications such as redundancy depend on the quality of the initial surgery. Despite a complex and time-consuming procedure requiring at least three or four digestive anastomoses, reported long term functional outcomes of colon interposition are good, with an acceptable operative risk. Thus, in very selected indications, colon interposition could be seen as a valuable alternative for esophageal replacement when stomach cannot be considered. This review aims at briefly defining “when” and “how” to perform a coloplasty through demonstrative videos.

**Keywords:** Esophageal surgery; colon interposition; esophageal cancer; esophageal motility dysfunction; benign esophageal disease

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## Introduction

Colon interposition has been used since the beginning of the 20<sup>th</sup> century as a substitute for esophagus. Historically the first coloplasty was realised by Kelling in 1911, and the first successful use of a colon after esophagectomy in 1914 by Von Hacker (1,2). Afterwards colon became the organ of choice for esophageal replacement (3).

In the second part of the 20<sup>th</sup> century, the stomach was admitted as the first choice for reconstruction after esophagectomy, in particular if performed for esophageal cancer (4,5). The procedure is fast, safe, standardized, requires a single anastomosis and can be performed through

a minimally invasive approach. Moreover, the stomach has a good vascularization, and presents a low leakage and necrosis rate, with good functional results (6,7).

Nowadays, colon interposition is mainly chosen as a second line treatment when the stomach cannot be used or for tumors of the upper esophagus or the hypopharynx where the length of the stomach is expected to be too short. Some centers reserve colonic interposition for young patients with benign disease with a long-life expectancy because of its relative good long-term functional outcomes (3,8-20).

This review aims at briefly defining “when” and “how” to perform a coloplasty.

**Table 1** Respective advantages and disadvantages of esophageal reconstruction with gastric pull-up, colon interposition and jejunal interposition

	Gastric pull-up	Colon interposition	Jejunal interposition
Advantages	Fast and safe procedure; stomach easily prepared; sufficient length to reach the neck; standardized technique; one single anastomosis; dependable vascularization low rate of necrosis; minimally-invasive surgery	Long and short colon; gastric reservoir; best functional results and quality of life; reduced delayed gastric emptying; reduced reflux; generous resection margins of distal tumors; outside the field of irradiation for distal tumors (preoperative radiotherapy)	Anterograde segmental contraction; sterile environment; low leakage rate
Disadvantages	Significant loss of capacity of the gastric reservoir; reflux esophagitis (30–50%); Barrett esophagus in the remnant esophagus; shorter distal margin for distal esophageal cancer or GEJ tumor; within field of radiation therapy for distal tumors (preoperative radiotherapy)	Complex procedure, longer operative time; limits: (I) aortic aneurysm; (II) previous abdominal or colic surgery; (III) colonic disease (inflammatory bowel disease); preoperative bowel preparation needed; Higher rate of necrosis, morbidity and mortality; 3 or 4 anastomoses; redundancy	Technically extremely complex; supercharged (microvascular anastomosis); experienced center; limitation in the length; exceptional indications

### Eso-coloplasty: when?

Four situations can be considered where colon can be indicated for reestablishment of the digestive continuity after esophagectomy.

#### *The stomach is not acceptable as a substitute*

When the stomach is not suitable for the esophageal reconstruction, another substitute has to be considered. This situation can be seen in case of:

- Previous gastric surgery (metachronous cancer, history of peptic ulceration...);
- Failed gastric pull-up (extensive necrosis or intractable leakage...);
- Doubtful viability (caustic burn lesion) or if the gastric vascularization has been compromised during the surgery (11,15,17,21).

Two substitutes are available, either the colon or a jejunal graft. Compared to colon interposition, jejunal interposition is a more difficult procedure, dependent of the anatomy of the vascularization of the patient and needing an experienced team requiring most of the time a microvascular transposition to the supra aortic vessels (13,22–24). Advantages and disadvantages of each substitute are discussed in *Table 1*.

#### *The stomach has to be resected for oncological reasons*

When the patient presents a tumor of the gastro-esophageal junction (GEJ) classified Siewert III, a tumor with signet-

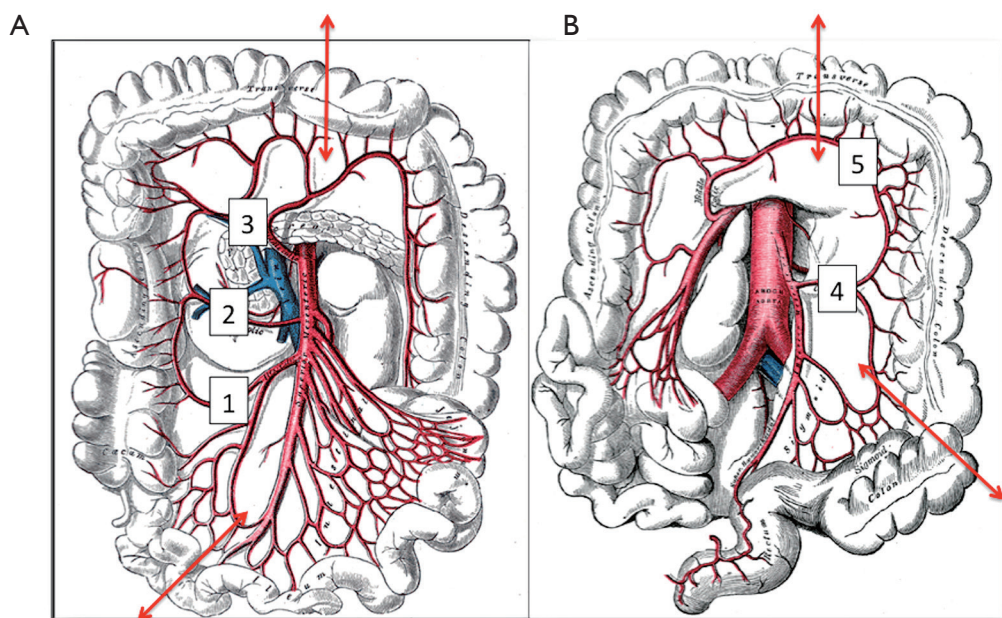
cells or a mucinous adenocarcinoma, the stomach must be resected for oncologic reasons during the esophagectomy (8,11,15,17). This total esophago-gastrectomy is a validated option to insure the completeness of the resection (25,26). The colon is then used with a Roux-en Y loop.

#### *The stomach is deliberately kept intact for functional outcomes*

For young patients presenting end-stage esophageal disorders (achalasia) or complex benign diseases, an esophagectomy with colon interposition is sometimes indicated with the deliberate intention to conserve the stomach intact (27–29). In those cases, some authors suggest to keep intact the stomach because of the expected good functional outcome with the coloplasty. In this situation, a functional reservoir is created and the patient has less acid and bile reflux then when performing a gastric interposition. These two conditions are considered as two main factors in the quality of life of young patients with a long life expectancy and especially in a benign disease setting (9,16). This paradigm can be applied for patients who suffered from a caustic burn of the esophagus or for all indications of esophageal replacement for benign diseases: benign tracheal fistula, non malignant stenosis (caustic, peptic, post-radiation), post traumatic, end-stage functional disorders (10,14,19,20,30,31).

#### *Pediatrics indications*

In addition, specific indications for pediatric cases can be



**Figure 1** Vascularisation of the colon applied to surgery. (A) Right colon vascularisation based on the superior mesenteric artery: [1] ileocolic artery; [2] right colic artery; [3] media colica; (B) left colon vascularisation based on the inferior mesenteric artery: [4] IMA; [5] Drummond marginal artery. IMA, inferior mesenteric artery.

considered. There is no consensus on what constitutes the best substitute for the esophageal replacement in congenital diseases such as atresia, severe strictures after caustic burn injuries or after complex peptic stenosis (32,33). For atresia, when primary anastomosis is not possible, gastric interposition is most often the first choice. Colon interposition remains a possibility, offering good results with more than 50% of the patients asymptomatic in the long term (34-37).

### Eso-coloplasty: how?

Several options are available when choosing colon interposition for esophageal replacement, depending of the vascularisation of the graft. Vascularisation is an essential step for the technical success of the surgery.

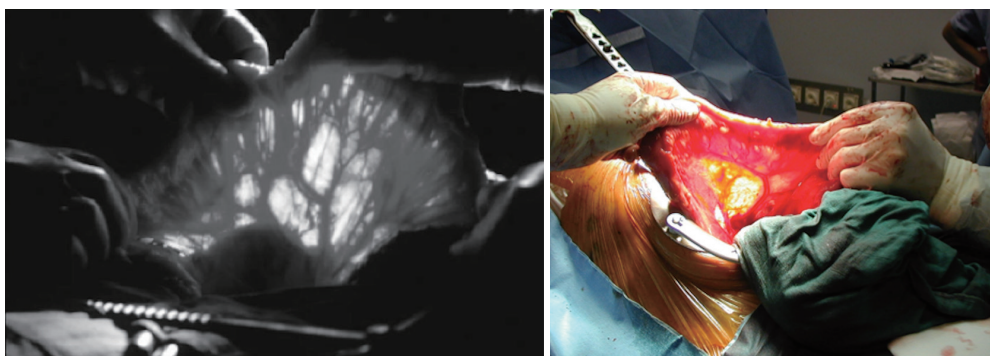
#### Vascular anatomy

The colon vascularisation is divided in two parts, one coming from the superior mesenteric artery (SMA) and the other one coming from the inferior mesenteric artery (IMA). This allows defining the right and the left colon grafts for colon interposition (*Figure 1*) (16,38). The right colon arterial vessels

come from the SMA. It goes from the end of the ileon to the first two thirds of the transverse colon, passing by the right hepatic flexure. The SMA gives birth first to the ileo-colic arteries, rarely absent, then to the right colic artery and finally to the media colica. Those last two arteries can be absent in about 25% cases each. Moreover anastomoses between the vessels can be lacking in 5% of cases, resulting in the ischemia of the colon graft. The left colon vascularisation, going from the last third of the transverse colon to the sigmoid colon, comes from the inferior mesenteric artery. The left colonic grafts include short transplant using the transverse colon and long ones using both the transverse and the left colon. The marginal artery of Drummond is the anastomosis between the right colic vessels and the left colic vessels. This artery is irregular, as it can be missing in 25% to 75%, and interrupted at the left colic angle in 5% of cases. When the IMA is occluded, for example in case of previous aortic surgery or atherosclerosis, there is a growth of this marginal artery, which can mask bad vascularisation of a left colonic graft and lead to the failure of the subsequent colonic interposition.

#### Pre-operative management

Though the vascularisation of the colon is an important



**Figure 2** Transillumination of the left colic vasculature.

factor for a successful operation, pre-operative angiography of the colic vessels is not systematically performed. There is no study in the literature proving pre-operative angiography achieves better results as anatomical variations are dealt with intra-operatively (39,40). Thus, in our opinion, it should be indicated for selected patients: in cases of previous abdominal surgery with potential involvement of the colonic vessels, previous surgery of the abdominal aorta, or in case of lower extremity claudication.

A colonoscopy should be performed for patients over 45 years old, symptomatic or with a history of arteriosclerosis (3,11,16). The colonoscopy allows to observe the mucosal trophicity and to check the absence of chronic ischemia, cancer or diverticulosis.

Previous to the surgery a bowel preparation is performed for all patients. When oral feeding is still possible cathartics and an appropriate diet should be given. For other patients, either a jejunostomy allows the administration of the cathartics, or iterative water enemas are used.

### *Surgical technique*

#### **Surgical approaches**

Several approaches can be used depending on the site of the proximal anastomosis and the need for a concomitant esophagectomy, either for a cancerous disease or a benign one. The whole procedure can be performed through a left thoraco-phreno-laparotomy in case of a short colonic transplant with an intra-thoracic anastomosis. The majority of colon interpositions are performed through a midline laparotomy for preparation of the colon associated with a left cervicotomy for the proximal anastomosis for long colonic transplant. If a concomitant esophagectomy is needed, it can be performed either through a trans-hiatal

approach, a right open thoracotomy or in the recent years through a right thoracoscopy (41).

#### **The choice of the graft and its preparation**

The first step of the procedure consists in the choice of an adequate transplant, ideally used in an iso-peristaltic position. The transverse colon, branched on the middle colic artery can be used as a short colic transplant, or as a long one if vascularized with left colonic vessels, birthed by the IMA. In our opinion, the transplant of choice is a left transverse colonic transplant, the arterial flow coming from the left vessels, and branched in an iso-peristaltic way (3,16,42). This technique provides enough length to the thorax or the neck with an excellent vascular supply in an isoperistaltic position. The colon is completely mobilized, from the caecum to the right than left flexures, and finally to the pelvic rim and the sigmoid colon. Once the colon can be fully moved, the arterial vascularisation is identified using transillumination. The left colonic vessels are seen, forming an arch from the descending colon up to the left flexure under the spleen (*Figures 2,3*).

With atraumatic vascular clamps, the right colic artery, the colica media and the collateral arcades at both extremities are occluded (*Figure 4*). This allows to check the correct arterial outflow in the colonic transplant, and to detect a previously masked occlusion of the IMA. During the same time, the venous outflow is also checked, verifying that there is no congestion. This whole step must be performed for at least 10 minutes (*Figure 5*).

Once the good arterial and venous vascularization have been confirmed, the proximal colon is transected. The proximal arcade is divided, but the distal one is preserved. The colica media is divided also, totally for long transplants, or only the left branch for short ones. The length of the





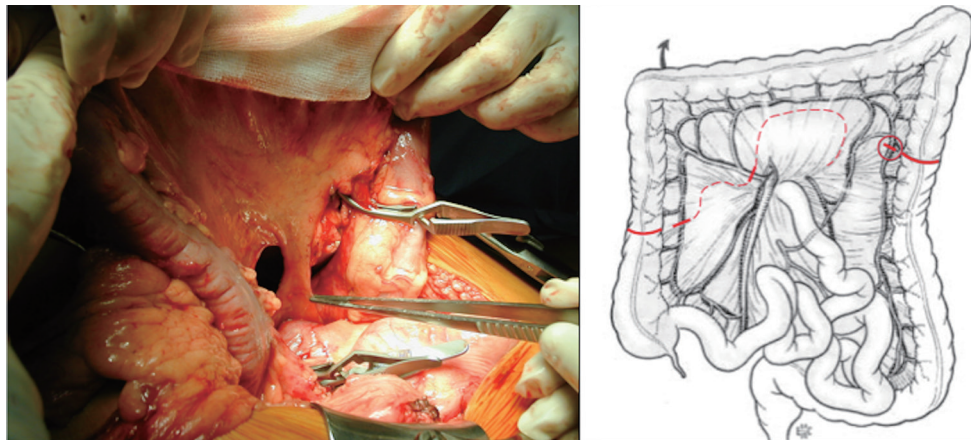
**Figure 3** Mobilisation of the colon. The colon is mobilised from the right hepatic flexure to the caecum, then from the left flexure to the sigmoid colon. When it is completely freed, the vessels are identified using transillumination (43).

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**Figure 4** Clamping of the colic arterial vessels. The length of available colon is measured, as is the length needed. The good arterial outflow of the transplant is tested using atraumatic clamps. Here the right collateral arcade is clamped (44).

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**Figure 5** Simulation of the graft vascularisation with the inferior mesenteric artery. The right colic artery, the middle colic artery and the marginal arteries are occluded with atraumatic clamps. The arterial outflow and the venous drainage through the left colic vessels are checked for at least 10 minutes.

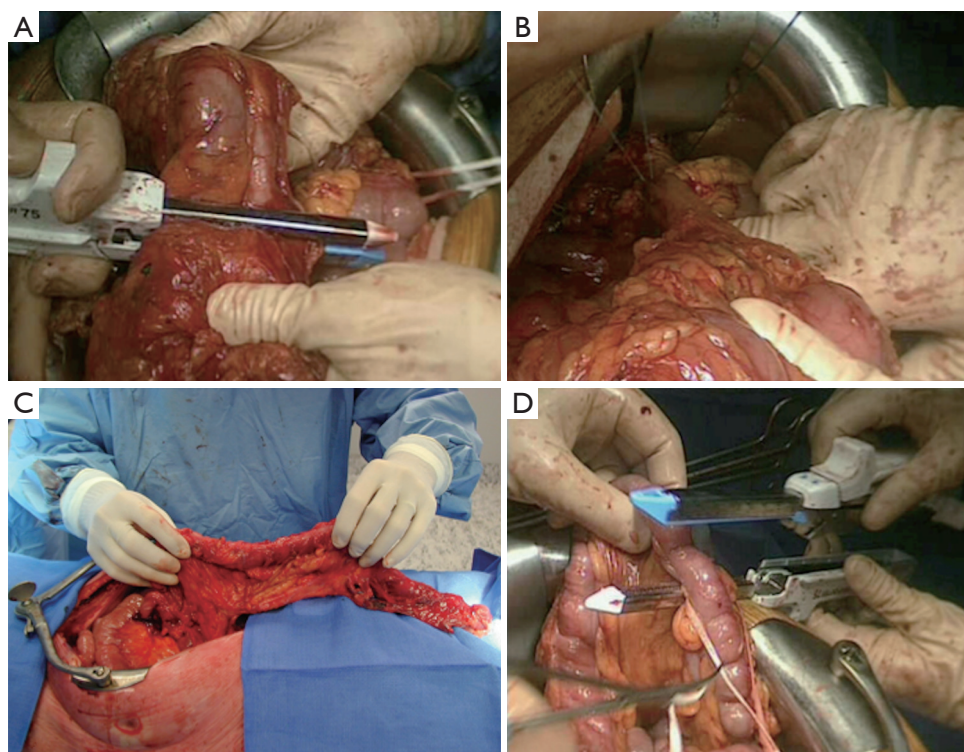
transplant needed is checked and finally the distal colon is transected also. The colonic transplant is then free on both ends, pedicled on the left colonic vessels (*Figure 6*).

Some teams use preferentially the terminal ileum and right colon as a long transplant. The steps and the strategy are the same, except that the main pedicle is the middle colic artery. The integrity of the artery is confirmed after clamping the ileo-colic artery, the right colic artery and the marginal arteries (15,17,45). The transverse colon in an isoperistaltic way, using the right colic artery or the middle colic artery as a main vessel, can be used as last resort. But the long-term outcome is disappointing, with bad functional

results and regurgitations (16).

#### The route of reconstruction

Whatever the colonic transplant used, either because of the team preferences or for surgical reasons, the route through which it will be positioned must be chosen with care. For long colonic transplants, the route depends essentially of an associated esophagectomy during the surgical procedure. The goal of this step is to achieve as straight a position as possible for the transplant, in order to avoid late complications such as redundancy (11,16). Whenever it is possible, the posterior mediastinum should be chosen



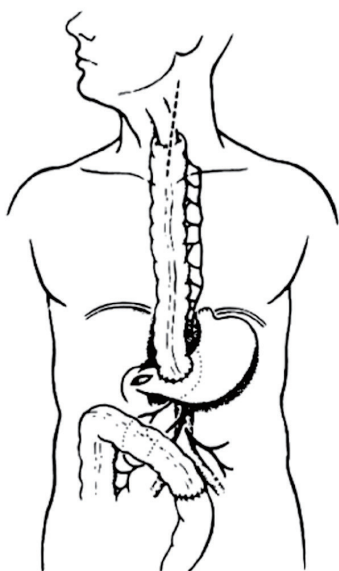
**Figure 6** The left colon transplant is freed and pedicled on the left colic vessels. (A) The proximal colon is transected; (B) the middle colic artery is transected; (C) the length of the colic transplant is checked; (D) the distal colon is transected.



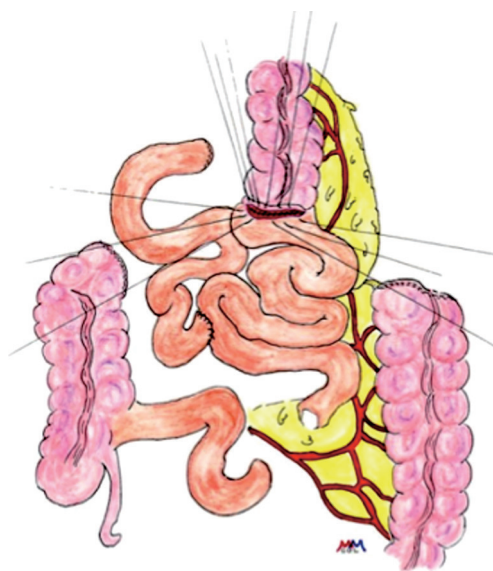
**Figure 7** The colic transplant is brought to the neck through a retro-sternal route. The upper thoracic inlet and the retro-sternal space are divided with blunt dissection. A loop is passed through the retro-sternal space from the cervicotomy to the hiatus. After it has been attached to the colonic transplant, it will be used to pull the colon to the neck. This whole step must be done precautiously in order not to compromise the colonic transplant (48). Available online: <http://www.asvide.com/articles/968>

(46,47). When not possible, either because the posterior mediastinum is not available (for example if the esophagus is left in place), or because a local recurrence or radiotherapy are expected, other routes can be chosen. Most often, a retrosternal position will be used, through the compression of the transplant can be bothering at the upper thoracic inlet (*Figure 7*). Some authors have suggested resecting the left part of the manubrium and the clavicle (49). To avoid kinking of the transplant, care should be taken not to open both pleura. In case of previous sternotomy, or radiation of the thorax, the retrosternal route can be unavailable. The transplant can then be positioned through a sub-cutaneous route (50). This route also has been chosen successfully as a first choice for some teams. The use of tissue expanders has helped to avoid the downfall of this route, which is too tight tunnels, causing post-operative dysphagia. Finally the colon graft can be positioned through a trans-pleural route (51). Though this route should be avoid if possible, as it can easily lead to dilatation of the transplant and colon redundancy.

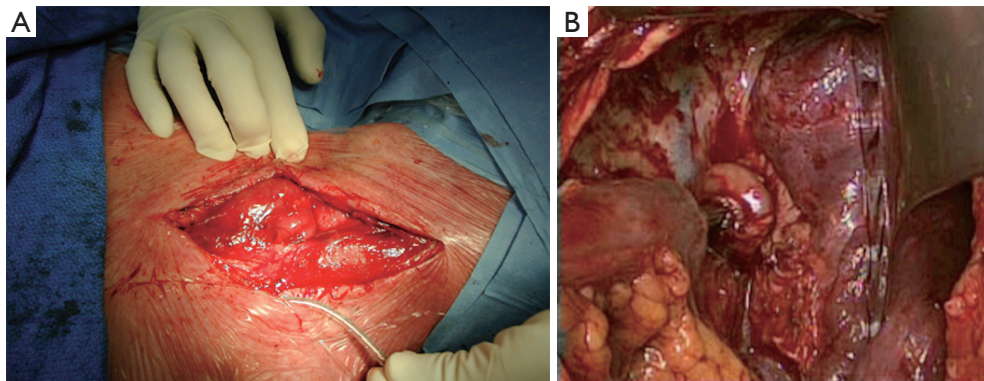




**Figure 8** Preservation of the stomach during a colon interposition. The colo-gastric anastomosis is performed at the posterior side of the antrum and is associated with a pyloroplasty.



**Figure 9** Roux en Y loop. After a gastrectomy, two more anastomoses are needed when performing a colon interposition: a colo-jejunostomy and a jejuno-jenal anastomosis.



**Figure 10** Eso-colic anastomosis. (A) Hand-sewn cervical anastomosis; (B) mechanical intra-thoracic anastomosis.

### Digestive anastomoses

Once the colon transplant is correctly positioned from the abdomen to the neck or to the thorax, the last step of the operation lays in performing the anastomoses. If the stomach was preserved, three anastomoses are needed: the eso-colic anastomosis or eso-ileal if a right colon was chosen, the colo-gastric anastomosis, and finally the colo-colic one. When a gastrectomy is performed, the colo-gastric anastomosis is replaced with a colo-jejunostomy and a jejuno-jenal anastomosis (Roux-en-Y loop) (Figures 8,9). The eso-colic anastomosis may be hand-sewn or mechanical with a circular stapling device. It must be performed first

to ensure that the colon transplant has an optimal length and prevent redundancy (11,49,52). We usually perform a hand-sewn anastomosis, with two running sutures of absorbable 3.0 suture (Figures 10,11). Intra-thoracic anastomoses can be performed mechanically. The colo-gastric anastomosis is best done at the posterior side of the antrum and is associated with a pyloroplasty. We perform an end-to-side anastomosis, with two running sutures of absorbable 3.0 stitches.

In order to improve outcomes of colon interposition, an additional step using microsurgery has been introduced since 2003 (54). “Superdrainage” consists in performing

a venous anastomosis in order to avoid congestion of the transplant. For right colic transplants it can be performed between the ileo-colic vein or the terminal ileal vein and the anterior or exterior jugular vein, or the internal thoracic vein (17,55). On the other hand, “supercharged colic interposition” is an arterial anastomosis to avoid ischemic necrosis of the graft. For right colic transplants

it is performed between the internal thoracic and the ileo-colic arteries (17). For left ones between the stump of the sigmoid artery and the superior thyroid artery or the facial artery (56,57). Several publications report the successful use of those techniques, though the number of procedures must be increased to truly evaluate the impact of superdrainage and supercharged on colon interposition outcomes (15,17,54-57). Furthermore, the length of the procedures is greatly increased and must be taken into account in an already difficult and long operation.



**Figure 11** Hand-sewn cervical eso-colic anastomosis. The posterior part of the anastomosis is performed first. A resorbable 3.0 suture is used for the first layer, and a slowly resorbable one for the second. After the naso-gastric tube has been placed through the colonic transplant, the anterior wall of the anastomosis is performed in the same way (53).

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## Discussion

Colon interposition is a complex operation, with specific indications. Over time the indications of colonic interposition have changed. Colon interposition is nowadays reserved for selected patients with esophageal cancer when the stomach is unavailable or has to be resected or for benign diseases of the esophagus (3,8-20).

In the literature, the reported post-operative mortality of the procedure ranges from 0 to more than 16%, with an associated risk of graft necrosis going from 0 to 10%, and anastomosis leak from 0 to 15% (Table 2) (3,8,9, 11-15,47,58-63). Risk factors for conduit ischemia such as diabetes, cardio-vascular diseases and COPD have been identified, and should be optimized pre-operatively (64). In addition, for anastomotic leak, neo-adjuvant therapy and

**Table 2** Mortality, graft necrosis and anastomotic leak rates of colon interposition in the literature

Author	Year	N	Mortality (%)	Graft necrosis (%)	Anastomotic leak (%)
Curet-Scott	1987	53	3.8	7.5	9.4
Isolauri	1987	248	16.0	3.0	4.0
DeMeester	1988	92	9.0	3.4	4.0
Cerfolio	1995	32	9.4	6.2	3.3
Thomas	1997	60	8.3	5.0	10.0
Mansour	1997	129	5.9	3.0	14.8
Wain	1999	52	4.0	5.8	5.8
DeMeester	2001	85	4.7	NA	9.4
Davis	2003	42	16.7	2.4	14.3
Knezevic	2007	336	4.2	2.4	9.2
Motoyama	2007	34	0	0	9.0
Doki	2008	28	Unknown	0	46.0
Mine	2009	95	5.3	0	13.0
Klink	2010	43	16.0	9.0	13.0
Kesler	2013	11	9.0	Unknown	9.0



conduit ischemia have also been described as risk factors.

The surgical management of a failed colon transplant in the early post-operative period can be challenging. When faced with a colon graft necrosis, as much viable conduct should be preserved in view of future reconstruction (49). Associated measures such as control of the sepsis, limitation of the inflammation surrounding the bed of the conduit, and performing an optimal nutritional resuscitation, are mandatory to improve the outcome.

In the early post-operative period, patients complain of dysphagia, diarrhea, reflux and dumping syndrome. Symptoms improve in the post-operative course (15). Late complications are frequent and can lead to further invasive treatments. Thus redundancy of the colon transplant is reported in 0 to 40% of cases and can lead to re-intervention, though the exact number of revision surgery is unknown (9,11,12,14,47,52,60,65). Anastomosis stricture is found in 0 to 40% of cases, and is most of the time successfully managed with endoscopic dilatations (3,9,11,12,14,47,52,59,60,65). It is increased for over-weight patients (continuous variable) and patients with a history of conduit ischemia and/or anastomotic leak (64). Chronic aspirations are needed in less than 10% of patients, and complications such as col-cutaneous or colo-bronchic fistulae, and secondary cancer of the transplant remain unusual (66-68).

In the literature, the reported quality of life after colon interposition is usually good (3,14,37,69-71). Though gastric pull-up after esophagectomy has been reported to have good results, the main complication in the long term is the presence of biliary reflux and secondary reflux disease in the conduit (7,72). For benign diseases, performing a vagal-sparing esophagectomy allows to conserve a fully innervated stomach and gastro-intestinal tract. Thus, there is no delayed stomach emptying, and the usual symptoms present after gastric pull-up decrease. If the resection of the vagus nerves is needed, the delayed emptying of the stomach can be prevented with a partial gastrectomy (73). In the long term, colon interposition allows a better quality of life, with less esophagitis (74). Notwithstanding the complexity of the procedure, this is why colon interposition is chosen over gastric pull-up for young patients with a long life expectancy needing an esophagectomy for benign diseases.

## Conclusions

The colon is a good substitute for the esophagus in

selected situations, with several options available for the reconstruction. The procedure can be long and complex, with three or four anastomoses needed. Even if there is a high rate of redundancy in the long-term with an eventual need for re-intervention, the colon provides durable and satisfactory alimentary comfort, with an acceptable operative risk.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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