

Colon Reconstruction and Esophageal Reconstructive Surgery

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Abstract

Esophageal reconstruction using colon graft was investigated in this review. Since the first use of the colon for esophageal reconstruction by Kelling and Vulliet, the colon reconstruction became a reliable surgical option to reconstruct partially or totally the esophagus. Over the time, the efficacy of colon graft has been thoroughly evaluated and definitively attested by competent surgeons during the past three decades. The mortality has been significantly improved however the early morbidity is still slightly higher compared to gastric reconstruction.

Despite the increased operative time and number of anastomoses, the advantages of a colon graft become apparent including its relatively straight mesentery, its status as an enough long graft to be pulled up to the neck, its low incidence of disease, its resistance gastroesophageal reflux and its long-term good functional results.

Compared to right colon, the left colon has less variation in blood supply and a smaller lumen diameter which matches perfectly with esophageal lumen. Colon reconstruction in an isoperistaltic fashion is the standard in order to prevent regurgitation and improve food transit. The posterior mediastinum and the substernal route are the most commonly route used in esophageal reconstruction. However in case of substernal colon reconstruction, as recommended by authors, the thoracic inlet should be enlarged by the partial remove of the manubrium and the left clavicle to ensure there is no compression on the transposed graft at the level of the thoracic inlet. The selection of appropriate colon graft should be based on the adequacy of blood supply and the length of reconstruction. Thereafter microvessel anastomosis should be added in cases where graft ischemia might occur.

Introduction

Esophageal reconstruction is completely different from the reconstruction of the other parts of abdominal digestive tract. In abdominal surgery; gastrointestinal continuity can be reconstructed with direct anastomosis or interposition of the mobilized digestive segment. During esophageal reconstruction, it is necessary to use an abdominal intestinal segment and to pull it up through a route to reach the oral stump of esophagus which lies at the cervical site or at the upper part of the thoracic cavity. So in such situation the length of reconstruction complicates surgery with more technical difficulties to select and to prepare an adequate intestinal graft with sufficient length and good vascular supply. The reconstruction of a long transplant requires more long intestinal segment to be used with the sacrifice of the blood supply leading to reduced blood circulation to the selected graft.

The key point of a successful esophageal reconstruction is to avoid cervical anastomosis tension by using a transplant with sufficient length and both arterial and venous good blood supply. Since the beginning of the 20th century, techniques for reconstructive esophageal surgery have included the use of colonic conduits. Firstly the anatomic bases of using the colon as a graft either to replace or bypass the malfunctioned esophagus were introduced independently by Kelling [1] and Vulliet [2]. In the same year, Kelling [1] performed the first esophageal reconstruction by interposing subcutaneously the transverse colon without performing cervical anastomosis. Three years after, von Hacker reported the first successful colonic reconstruction including an esophagocolonic anastomosis [3]. On the fine and late in 1950, Orsoni and Lemaire reported a successful one-stage colonic esophageal reconstruction [4]. Belsey published the first large series of esophageal reconstruction with a left isoperistaltic colon [5]. Over the years, the original technique has been improved and the use of the colon as an esophageal substitute has become popular until gastric esophageal reconstruction was accepted widely [5-7]. At present, gastric graft is the first choice to reconstruct esophagus and gastric reconstruction constitutes the standard procedure because of its simplicity. However, the stomach cannot always be employed as a graft and cases that require colonic reconstruction are not rare. Subsequently, with

Keywords: Esophageal reconstruction; Colon graft; Route of reconstruction; Morbidity

improvements in the surgical techniques and in postoperative care, the mortality of colonic reconstruction has been increasingly reduced. Despite a slightly higher rate of morbidity, the colic graft interposition has satisfactory long-term functional results. Performed by experienced hands, colonic reconstruction has become a safer and more applied surgical procedure to reconstruct the esophagus in both benign and malignant conditions with low mortality and acceptable morbidity. Therefore, it is necessary to be more familiar with colonic reconstruction than ever before in order to decrease the morbidity and mortality associated with the procedure.

The surgical procedures used for colonic reconstruction vary widely in the type and the direction of graft segment, the route of reconstruction and the addition of vascular supercharge of graft. We herein investigate the advantages and disadvantages of various surgical procedures by reviewing the previous reported publications on colonic esophageal reconstruction, and determine the optimal procedure.

Indications for Colonic Reconstruction

The decision of which organ to be used for esophageal reconstruction is based on multiple factors: Esophagus disease, length of reconstruction, digestive organ available and experience and preference of surgeon. Some authors considered that gastric interposition was the procedure of choice for most patients with both benign and malignant disease [8-11]. Other authors have suggested that the colon is the best conduit to construct the esophagus and to restore swallowing function mainly because of an increased incidence of aspiration and reflux with gastric conduit [12-21]. Stomach has the disadvantages of long term gastroesophageal reflux which can lead to complications such esophageal ulceration and anastomotic stenosis. In the cases of diffused injuries with pharyngo-esophageal stenosis, the stomach is not sufficient long to reach the basis of the tongue to realize a pharyngoplasty. In massive caustic ingestion, the stomach is often injured and its use as an esophageal substitute is impossible. Many authors preferred colon reconstruction and considered that the colon is the best esophageal substitute to restore deglutition function in light of its anatomic and physiologic features, including its relatively straight mesentery, increased length that can be mobilized on vascular pedicle, low incidence of disease, resistance to chronic gastric reflux and the long-term good functional results of colon reconstruction. However the completion of the digestive tract continuity during colon reconstruction requires three or four anastomoses and more time to achieve the procedure. The reported incidence of necrosis in gastric and colonic reconstructions was 1% and 2.4 respectively. Compared to gastric interposition, colon reconstruction comes with slightly high risk of graft necrosis. Cervical anastomotic leakage in both gastric and colon reconstruction is comparable [12-18,22-41]. In Western countries, esophageal reconstruction by colonic interposition is preferred, even in the patients who are capable to undergo reconstruction with the gastric tube in order to avoid gastroesophageal reflux, which appears to be

beneficial for preventing the development of Barrett's esophagus and adenocarcinoma [42]. Colon reconstruction is relatively a complex surgical procedure hence experience and surgical skills are needed. In our institute, the first choice is for the left colic graft supplied by the left colic pedicle. Our preference for left colon reconstruction procedure lies firstly on the anatomic and physiologic features of left colon cited above and secondly on the reported results and our personal results obtained by employing this surgical procedure for esophageal reconstruction.

Surgical Anatomy of the Arterial Supply to the Colon

The most important point regarding the reconstructive surgery using colon graft is the preparation of colon segment with sufficient length and good blood supply that greatly affects the surgical outcome. The in-depth knowledge of colon vascular anatomy and its variations is essential to select an optimal graft. The variations of the colon blood supply were investigated in detailed anatomic studies based on dissections [43,44]. It is therefore, necessary to carefully inspect the blood vessel in the mesentery and to select the colon segment based on regions that has less variation and less weak points in the arterial vessels. When selecting the colon segment to be the future graft, some points should be taken in consideration: Three arterial branches originate from the Superior Mesenteric Artery (SMA), namely the ileocolic, right colic, and middle colic arteries which are directed respectively toward the ilecolon, the ascending colon, and the transverse colon. This vascular distribution is observed in 68% of cases [44,45]. The ileocolic artery appears to be the most consistent structure however the arterial anastomoses (marginal artery) between the ileocolic and right colic vessels are absent in up to 70% of patients [3,8]. The right colic artery is absent in 12.6% of cases [44] and may be an independent branch of the SMA (38%) and can share a common trunk with the middle colic artery in up to 52% of cases. The recurrent iliac artery is absent in 61% of the cases and the cecocolic anastomosis is absent in 10%; therefore, the terminal portion of the ileum is generally a poorly vascularized area that should be avoided [43].

The middle colic artery originates from the SMA as a separate branch in 44% of cases, and has a common trunk in conjugation with the right colic artery in 52% of the cases [43]. It may be absent in less than 10% of the cases. The anastomosis of the right and left branches of the left colic artery at the Griffith point is precarious in 32% and absent in 7% of the cases [43]. The left colic artery is the most constant one of the left colon and communications between left colic and middle colic arteries are more abundant than that between right colic and middle colic arteries.

Optimal Design of the Colon Graft

There are six main selection patterns of grafts according to the colon segment and the pedicled vessel used (**Table 1**). The best colon segment with regard to the blood supply and length

should be selected individually after considering the advantages and disadvantages of each type of graft design.

Table 1: Types of colon reconstruction.

Blood supply	Colon segment as graft	Peristalsis direction
Ileocolic artery	Ascending+transverse	Antiperistalsis
Right colic artery	Ileum+ascending	Isoperistalsis
	Ascending+transverse	Antiperistalsis
Middle colic artery	Ileum+transverse	Isoperistalsis
	Transverse+descending	Antiperistalsis
Left colic artery	Transverse+descending	Isoperistalsis

Right colon versus left colon

The disadvantages of right colon include a high variation in blood vessels and a larger diameter and therefore larger difference in size compared to the esophagus, and sometimes there is excess dilatation of the cecum. On the other hand, the left colon has a more reliable blood supply, provides adequate length for reconstruction, and is smaller in diameter and less prone to dilatation. A common disadvantage of reconstruction with colon segments from each side is regurgitation [46,47]. Although the left colon has advantages compared with the right colon, reconstruction with the left colon segment is not dominant in the literature (**Table 2**). Esophageal conduit necrosis is an uncommon complication but disastrous. Compared to gastric graft, a slightly higher rate of ischemic necrosis after using colon graft has been reported by some authors. Davis et al., had a preference for the right colon, reported a rate of 2.4% of colon ischemia after right colon interposition [22], whereas DeMeester et al. reported a rate of 4.7% of intraoperative graft ischemia after left colon interposition [15]. Boukerrouche reported a large series of 105 patients who underwent a substernal left colon interposition, a rate of 1.9% of graft necrosis which was being comparable to that of right colonic graft necrosis [48]. Careful selection of patients for surgery, preoperative evaluation of the proposed conduit and meticulous operative technique are the best defences against conduit ischemia. Postoperatively, surgeons should have a high index of suspicion for this complication. Reconstruction with right and transverse colon based on the middle colic vessels [22,49] is desirable with respect to avoiding the region of the terminal ileum and Griffith's point. However, the disadvantage is the differences in the diameter between the esophagus and the colon. Ileocolon graft has the advantage that the size of the ileum matches well with that of the esophagus, and the Bauhin valve may temporarily prevent postoperative regurgitation. However, the terminal ileum has a weak blood supply which constitutes a disadvantage of ileocolon graft. The near-invariability of the left colonic artery, the better plasticity of its mesocolon, and its smaller lumen are the most advantages of the left colon to be selected as a graft for esophageal reconstruction.

Each type of colon graft has advantages and disadvantages. Therefore, the priority for the selection of the graft should be

based on the adequacy of blood supply and the length of reconstruction. The decision about which colic segment to be selected, is made intraoperatively and depends on anatomic conditions and the surgeon's preferences and experience. So the colon segment should be selected very carefully after detailed observation of the arterial anatomy by mesentery Tran's illumination and after assessing the adequacy of the circulation to the graft by a traumatic clamping test. The preference for whether right or left colon depends also on the of the surgeon's preference and experience however the surgeon must be familiar with others procedures as an optional alternative when a surgical technical problem arises [39,50].

Isoperistaltic or Antiperistaltic Orientation of graft

Motility and the evacuation function of isoperistaltic and antiperistaltic colon segments were investigated by Othersen and Clatworthy in an animal experimental study [51]. The results showed that the peristaltic sequences were significantly more frequent in peristaltic segment than that in antiperistaltic segment (77% and 22% respectively) [51]. Furthermore, the evacuation for solid food was significantly longer for the antiperistaltic colon than that for peristaltic one (69 min and 35 min respectively). In addition, the regurgitation of food was observed more frequently in the dogs that received the antiperistaltic colon graft. So from an experimental functional point of view, the isoperistaltic graft reconstruction should be considered more suitable and more preferable for reconstruction. In the literature, as shown in **Table 2**, the peristaltic reconstruction is performed as a standard procedure at most institutions [22,28,30,32-35,40,41,52-55] reported by authors who used colon graft in antiperistaltic direction [47,48], acid regurgitation and risk of aspiration were significantly more important in the antiperistaltic reconstruction [25,49,56]. Consequently, considering the risk of aspiration associated with regurgitation in the antiperistaltic reconstruction and the results of experimental studies, isoperistaltic reconstruction should therefore be employed instead of antiperistaltic reconstruction whenever possible. The type of colon graft

should be selected among three patterns of peristaltic segments on the basis of the adequacy of the blood supply and the length of reconstruction. Isoperistaltic left colon segment based on the left colic artery is the first choice of colon graft design in our institute is an isoperistaltic ileocolon segment with the long ileum. The reason for this is because the use of the ileocolon graft has an advantage in the secondary reconstruction if the first graft fails, as well as the various advantages described above. The reconstruction with the left-transverse colon based on the left colic artery accompanied with sacrifice of the middle colic artery has a disadvantage in that there is no candidate for a long graft except the ascending-ileocolon segment, whereas the ileocolon reconstruction based on the right or ileocolic artery preserving the middle colic artery is advantageous because the ascending-transverse colon and the left colon segments are both candidates as long alternative grafts if the first graft fails.

Routes for Reconstruction

During esophageal reconstruction, there are multiple options for the placement of the digestive conduit; so there are three placement sites, the posterior mediastinum, the substernal tunnel and the subcutaneous space (**Table 2**). The subcutaneous route is the longest and has strong angulation at its cervical extremity when entering the neck and as at the upper abdominal region when it leaves the abdominal cavity and passes over the xiphisternum, so this route is at high risk of graft necrosis. As reported by authors, the high incidence of graft gangrene associated with the subcutaneous route suggests that only when other routes are not available or suitable, the subcutaneous route should be used [21]. Therefore, the two most commonly employed options are the posterior mediastinum and the substernal route.

Table 2: Surgical procedures used in past studies of colonic reconstruction.

Author Refs.	Year	Segment of the colon			Peristalsis of the graft			Routes for reconstruction		
		Right	Transverse	Left	Isoperistalsis	Antiperistalsis	Orthotopic	Retrosternal	Subcutaneous	Thoracic
Isolauri et al. [27]	1987	67	46	135	103	145	231	17	0	0
DeMeester et al. [15]	1988	7	0	85	92	0	48	38	2	0
Cerfolio et al. [13]	1995	12	0	20	30	2	13	19	0	0
Mansour et al. [31]	1997	85	4	18	-	-	90 ^c	41 ^c	2 ^c	0
Thomas et al. [32]	1997	7	0	53	56	4	38	21	1	0
Fujita et al. [33]	1997	3	0	50	53	0	0	10	43	0
Davis et al. [22]	2003	42	0	0	42	0	26	11	1	0
Popovici [16]	2003	115	0	246	-	-	0	293	48	6
Cheng et al. [55]	2005	0	13	32	40	5	-	-	-	-
Shirakawa et al. [40]	2006	46	0	5	51	0	0	0	51	0
Motoyama et al. [41]	2007	30	0	4	34	0	34	0	0	0
Mine et al. [71]	2009	30	0	26	-	-	3	92	0	0
Klink et al. [72]	2010	18	0	25	15	28	34	9	0	0
Boukerrache et al. [48]	2016	1	0	104	105	-	-	105	-	-

The posterior mediastinum is the shortest and most direct route, thereby relaxing tension to the cervical anastomosis site and reducing the kinking and twisting risk of graft vascular pedicle [30]. The use of the posterior mediastinum needs the ablation of the native esophagus. In some situations, the access to the posterior mediastinum is difficult or technically not possible [57], such as in case of esophageal caustic stricture, the scarred esophagus adheres intimately to adjacent

organs which make its dissection risky and haemorrhagic exposing the patient to an additional risk of complications [58]. This route also has a high rate of mortality if graft necrosis occurs, and it is naturally not indicated for palliative cases because the posterior mediastinum is a tumour bed. Even in curative resection, the existence of the reconstructed graft in the esophagus bed gives a limitation of the dose and field in chemoradiotherapy and/or an increase in the risk of

surgical therapy for mediastinal tumour recurrence. Furthermore, it is difficult to treat a second primary cancer occurring in the transplanted colon because iterative access to the posterior mediastinum is at high risk of operative complications due to the posterior location and narrow space. These disadvantages of the posterior mediastinal route have prompted some surgeons to advocate an alternate route of reconstruction, namely the substernal approach [59]. The substernal route has been an alternative for delayed esophageal reconstruction or when access to the posterior mediastinum is difficult or technically not possible [57,59]. The substernal route is of easy realisation without thoracic approach and respiratory repercussions. Substernal reconstruction is an ideal indication for esophageal palliative surgery in advanced cases. There is no restriction in treatment for mediastinal recurrence substernal route is advantageous because it is easy to approach the graft if a second primary tumour of grafted colon occurs. Esophageal reconstruction through substernal route is widely employed by surgeons in caustic stricture because; the scarred esophagus is often left in place and its ablation is at high risk of post-operative complications. The substernal route has high risk of compression of the graft at the thoracic inlet which can lead to mechanical ischemia of the cervical portion of the graft causing a leakage or localized necrosis. Therefore, the venous blood flow is very sensitive to a mechanical obstacle, which is thought to be the usual precipitating event for necrosis. To prevent this event, some surgeons suggested enlarging the thoracic inlet by removing the left half of manubrium and internal third of clavicle [11,15,42,49,60-62]. This procedure allows to easy access to the left internal thoracic vessels which can be useful for supercharge of graft by performing microvessel anastomosis. The straightness of the graft is primordial parameter since food bolus travels mainly by gravity in colon graft [32] so it is very important to select a graft with adequate length to avoid excess in graft length which can lead to redundancy. Colon redundancy leads to mechanical dysfunction of the graft, causing disabling symptoms that impair the quality of life. As reported by authors, the clearance of both liquid and solid food was better in reconstruction performed via the posterior mediastinal route than via the retrosternal route [63]. The posterior mediastinal and retrosternal routes are associated with similar rates of immediate postoperative complications [64]. Compared to posterior mediastinum, the substernal route is associated with a slightly higher rate of cervical anastomotic leak linked partially to the compression of the colon graft at the level of thoracic inlet. However, the opening of the thoracic inlet may reduce the incidence of cervical leak [65] and its enlargement is suggested by many surgeons performing esophageal substernal reconstruction [11,42,49,50,60-62,65,66]. On the other hand, the risk of postoperative regurgitation is increased in posterior mediastinal colonic reconstruction [67]. To reduce postoperative regurgitation, authors [28,67,68] suggested that cologastric anastomosis should be performed on the posterior surface of the stomach at the point one third of the distance between the tip of the fundus to the pylorus. Regarding to functional results, both posterior mediastinal and retrosternal routes are associated with similar long-term outcomes [64].

Regardless of the route used for reconstruction, it is important of checking constantly the position of the graft vessels to ensure there is no mechanical compression that may impair the vascular supply of the graft, and to select a graft with sufficient length to avoid thus tension at the anastomotic site.

The posterior mediastinum is preferred for immediate reconstruction after esophagectomy and the substernal route for delayed reconstruction. However the selection of the pull-up route should be based on the nature of disease, benign or malignant and the functional aspect.

We prefer the use of substernal approach for esophageal malignant conditions regarding the possibility of mediastinal recurrence, and for caustic stricture when the diseased esophagus is left in place. We use the posterior mediastinal reconstruction for benign conditions. However, when using the substernal approach, we feel it is essential to enlarge the thoracic inlet by removing the left half of the manubrium and the sternal head of the left clavicle to ensure there is no compression on the grafted colon. Sometimes and when necessary the excision should be extended to the medial end of the first and second rib in order to perform a vascular supercharge of the graft.

Surgical Outcome

Mortality and morbidity

The mortality rates for esophageal reconstructive surgery by colonic interposition for three decades ending in 1961, 1971, and 1981, were 11.1%, 7.5%, and 4.9% for benign conditions lesions, and 21.8%, 24.5%, and 16.6% for malignant conditions, respectively [69]. This mortality evolution through three decades demonstrated an improvement over time. Twenty five published reports were reviewed and the results were divided into three decades ending in 1990, 2000, and 2010 [22-41,70]. Surgeries were performed for both benign and malignant conditions. The mortality rates were 8.2%, 7.9%, and 5.8%, respectively, showing a tendency of further decrease over time. This improvement of mortality was linked to operative technique improvement and anaesthetic progress. The esophageal reconstruction by colon graft should be recognized as a surgical procedure with relatively high risk. The main cause of death was graft necrosis, followed by sepsis and adult respiratory distress syndrome [28,30-32,69]. Regarding to pulmonary complications, the incidence has been recently decreased firstly improvements in perioperative management and secondly by minimally invasive surgeries (thoracoscopy and laparoscopy). The most severe complication is the colon graft necrosis which is associated with high rate of death in absence of early diagnosis and adequate management. The difficulty is how to complete further digestive re-reconstruction which requires a panel of complex surgical procedures. The precautions to prevent graft necrosis include: meticulous dissection, selection of an optimal colon graft and avoiding twist by checking the position of the graft vessels because the venous flow is very sensitive to a mechanical obstacle. As demonstrated by operative findings,

venous thrombosis is thought to be the usual first event for necrosis. The incidence through three decades ending in 1961, 1971, and 1981 was 3.9%, 3.8%, and 2.4%, respectively (**Table 3**). It has been also decreased especially since 2001 [22-41,70]. This decrease of graft necrosis rate is explained by significant improvement of operative technique. These improvements of both perioperative management and operative technique contributed to decrease perioperative mortality. On the other hand, leakage of the esophagocolic or esophagoileal anastomosis was observed in 0%-54% (mean: 14.0%) of patients with colonic reconstruction (**Table 3**), which is still a high rate [22-41]. The most common complication encountered in esophageal reconstruction surgery is the cervical anastomotic leakage. So the rate of esophagocolic or esophagoileal anastomosis leakage varied largely and it was 0-47% (mean: 14.0%) in colon interposition [22-41,46]. Cervical anastomotic leakage rate is still significantly higher and should be improved. The cause of leakage is multifactorial but the most important factor is the poor nutritional status of patient which negatively impacts the anastomotic healing process. So improving nutritional conditions may reduce the risk to

develop anastomotic leakage. Anastomotic stricture was observed in 3-46.2% of patients (mean: 13.4%) (**Table 3**) [16,22,26-28,30,31,33,35,39-41,71-72]. Nearly 60% of anastomotic stricture resulted of healed leakage which the clinical expression of a poorly anastomotic healing. The anastomotic stricture should be treated conservatively and the first treatment is endoscopic balloon dilatation. Therefore, the surgery is indicated after lack of dilatation. In any case, graft necrosis, anastomotic leakage, and stricture are greatly influenced by the blood supply of the graft. Therefore, the selection of an optimal graft of the point of vascular blood supply, the necessity of checking constantly the position of graft vessels avoiding thus any compression or twisting are strongly recommended. Great care must be taken to avoid injury to both veins and arteries of the graft. Vascular supercharge of graft by microvessel anastomosis is an effective method to improve the quality of blood supply to the graft but its usefulness is limited to particular situations [23,33-40]. The main late complication of colonic interposition is the redundancy of the interposed colon graft [11,22,26,28,35,39,41].

Table 3: Postoperative complications observed in previous studies of colonic reconstruction.

Author	Year	No. of patients	Microvessel anastomosis	Mortality (%)	Morbidity (%)	Leakage (%)	Necrosis (%)	Necrosis Stenosis (%)	Redundancy (%)
Wilkins [24]	1980	100	0	9	40	14	7	-	-
Neville and Najem [25]	1983	84	0	4.8	13.1	8.3	2.4	-	-
Isolauri et al. [27]	1987	248	0	16	-	4	3	-	-
DeMeester et al. [15]	1988	92	0	8.7	15.2	4	3.4	4.3	3.4
Cerfolio et al. [13]	1995	32	2 (6.3%)	9.4	24	3.1	6.2	24	-
Mansour et al. [31]	1997	101	0	5.9	35.6	14.8	3.0	3.0	-
Thomas et al. [32]	1997	60	0	8.3	65	10	5	13.5	-
Wain et al. [14]	1999	52	1 (1.9%)	3.8	-	5.8	9.6	46.2	3.8
Hagen et al. [37]	2001	72	0	5.6	75	13	5.6	-	-
Fürst et al. [38]	2001	53	0	9.4	60	12	3.8	-	-
Davis et al. [22]	2003	42	0	16.7	-	14.3	2.4	20	2.4
Popovici [16]	2003	347	0	4.6	-	6.9	1.2	6.3	0.3
Shirakawa et al. [40]	2006	51	41 (80.4%)	0	35.3	7.8	0	13.7	-
Mine et al. [71]	2009	95	3 (3.5%)	3.2	64.2	13	0	6	-
Klink et al. [72]	2010	43	0	14	44	30	1	19	-
Boukerrouche et al. [48]	2016	105	0	1.7	26.6	13.3	1.9	7.6	1.9

Redundancy leads to retention of food and liquid in the graft, causing dysphagia, regurgitation and nocturnal aspiration. Reoperation is frequently performed for redundancy. It is consisted of the excision of the redundant portion of the colon graft, with reanastomosis of the colon

end-to-end. However, care must be taken to avoid injury to the vascular pedicle supplying the graft.

Is microvascular anastomosis necessary

Most institutions do not prefer performing supercharge and super drainage of the graft by adding microvessel anastomosis (**Table 3**). The routine use of microvascular surgery during esophageal reconstruction by colon interposition was unnecessary because no graft necrosis was in patients who underwent colon reconstruction without microvessel anastomosis [11,68]. In contrast, other authors observed no graft necrosis and low rate of cervical anastomotic leakage in patient who received colon reconstruction with microvessel anastomosis for supercharge and super drainage [23,33,40]. These authors concluded that clear advantages of additional microvessel anastomosis during colon reconstruction. However, there was no tendency showing a correlation between the addition of microvessel anastomosis and a low rate of anastomotic leakage in our analyses (**Table 3**). Therefore, the effectiveness of supercharge and super drainage of prevention of anastomotic leakage is uncertain because cause of anastomotic leakage is multifactorial and blood supply is a factor among others. No graft necrosis was observed in any of the four reports that added supercharge and super drainage in more than 80% of patients, thus suggesting that there is an advantage of addition of microvessel anastomosis regard to the prevention of graft necrosis [23,33,40,69]. Graft ischemia is often identified intraoperatively [28,31,35]. Patients who showed intraoperative graft ischemia, adding microvessel anastomosis became necessary to salvage the colon graft. Necrosis of the graft threatens the patient's life, and moreover induces major surgical stress due to the need for multiple and complex operations. Therefore, adding microvessel anastomosis should be considered whenever it is possible and imperative. The microvessel anastomosis was mainly performed between the proximal mesenteric vessels of the graft and the internal thoracic vessels namely left internal mammary artery in most cases, or in the cervical vessels in other cases, such as the transverse cervical artery or the branches of the external carotid artery and the internal or external jugular vein.

Conclusion

The colon graft is an alternative option for esophageal reconstruction when the stomach is injured or not applicable. According to the selected colon segment and its feeding vascular pedicle, the peristaltic direction of grafted colon and the graft placement, various surgical procedures can be considered for colonic reconstruction. Therefore, it is essential to choose the optimal surgical procedure on a case-by-case basis. Regardless of the situations, the blood supply of the colon graft is the most important factor which affects directly the postoperative results including mortality and morbidity. So the selection of the future colon graft and its relative vascular pedicle should be made very carefully after examination of the vessel anatomy and evaluation of the blood supply quality by the clamping test. Microvessel anastomosis should be added if there are any sign of blood supply inadequacy of the graft. Colon reconstruction is a relatively high risk procedure and it is necessary for surgeon to be familiar with this surgical

technique. Mortality has been significantly improved over the time by improvement of surgical technique and acquisition of experience. However, early morbidity is still slightly higher especially cervical anastomotic leakage. Colon graft is an excellent digestive organ for esophageal reconstruction. Performed by experienced surgeons, colon reconstruction is an excellent option with low mortality and acceptable morbidity.

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