International Journal of Hepatology & Gastroenterology

Review Article

Colon Graft Necrosis following Esophageal Reconstruction - a

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Submitted: 03 May 2017 **Approved:** 23 May 2017 **Published:** 29 May 2017

Citation this article: Boukerrouche A. Colon Graft Necrosis following Esophageal Reconstruction. Int J Hepatol Gastroenterol. 2017;3(1): 001-006.

ABSTRACT

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 diseased esophagus. Over the time, the efficacy of colon graft has been thoroughly evaluated and definitively attested by competent surgeons. However, the selection of colon segment and completion of the esophageal anastomosis constitute the greatest challenge during esophageal reconstruction. Furthermore, the selection of an optimal colon graft should be based on the adequacy of blood supply and the length of reconstruction. The viability and function of the graft affect greatly surgical outcome and functional results. Therefore, knowledge of risk factors, diagnosis, management and prevention of colon graft necrosis is key to understand and to perform successfully an esophageal reconstructive surgery.

Keywords: Esophageal reconstruction; Colon graft; Necrosis

INTRODUCTION

At the beginning of the 20th century, Kelling and Vulliet used the colon graft as an esophageal substitute [1,2]. Over the years, the original technique has been improved and the use of the colon as an esophageal substitute became popular and widely adopted until gastric esophageal reconstruction was accepted widely [3-5]. Both right and left colons are used to reconstruct the diseased esophagus. Each type of colon graft has advantages and disadvantages. The selection of the optimal graft is based on the adequacy of blood supply and the length of reconstruction. However, the selection of colon segment to be used is made intraoperatively. Such decision depends on the patient anatomic conditions and the reconstruction distance. The key point of a successful esophageal reconstruction is to ovoid cervical anastomosis tension by using an optimal graft with sufficient length, good blood supply and good venous drainage. The in-depth knowledge of colon vascular anatomy and its variations is essential to select an optimal graft. The graft necrosis is the most disastrous postoperative complication which is associated with high rate mortality in absence of early diagnosis and management. This serious complication affects greatly the surgical outcome and functional results. Therefore, knowledge of risk factors, diagnosis, management, and prevention of graft necrosis is a key to understand and to perform successfully an esophageal reconstructive surgery.

Colon features

The colon is the first digestive organ used to replace diseased esophagus. The colon reconstruction continued to be largely used until the gastric reconstruction was accepted as a surgical procedure to reconstruct the resected esophagus. Many authors have suggested that the colon graft is the best conduit to restore gut continuity and swallowing function after esophagectomy because mainly of an increased incidence of aspiration and reflux with gastric tube [6-14]. Preference of using colon graft lies on the anatomic and physiologic features of colon, including its relatively straight mesentery, increased length that can be mobilized on its vascular pedicle, its low incidence of disease, its resistance to chronic gastro-biliary reflux, its intrinsic peristalsis, its ability to replace partially or totally the diseased esophagus and using colon graft permits to perform much more aggressive gastric resections thus optimizing tumor removal in distal esophageal tumors.

The most important point regarding the colon segment selection is the blood supply and length of reconstruction. The length of reconstruction and graft blood supply affect greatly the surgical outcome. Therefore the good knowledge of colon vascular anatomy and its variations is essential to select an optimal colon graft with sufficient length and good blood supply.

The vascular supply to the colon is segmental: ileocolic, right colic, and middle colic originate from the Superior Mesenteric Artery (SMA) and are directed respectively toward the ilecolon, the ascending colon, and the transverse colon. Left colic and sigmoid arteries originate from Inferior Mesenteric Artery (MIA) and vascularize the left colon. All these vessels feed the marginal arterial arcade of Drummond which runs in close proximity and parallel to the colon wall and allows a great potential graft length for esophageal reconstruction [15]. This anatomy is perfectly studded and weakness points are well defined such the terminal portion of the ileum and the Griffith point which corresponds to the anastomosis between branches of the middle and left colic arteries. Therefore, it is necessary to carefully inspect the blood vessel in the mesentery and to select the colon segment based on region which has less variation and less weak points in the arterial vessels. According to the colon segment and its blood supply; there are six main selection patterns of grafts (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. The disadvantages of right colon includes a high variation in blood vessels and a larger diameter (therefore larger difference in size compared to the esophagus), and sometimes there is excess dilatation of the cecum. The 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. Indeed authors suggested to perform graft supercharge when using ileocolon segment. Compared to the right colon, the left colon has advantages has a more reliable blood supply, provides adequate length for reconstruction, has small diameter and is so less prone to dilatation. Both right and left colon can be used however the left colon is more preferable and this preference lies on the near-invariability of the left colonic artery in contrast with the vascular pattern of the right colon and its smaller lumen which matches perfectively with the esophageal lumen. Both isoperistaltic and antiperistaltic colon graft can be used to replace the resected esophagus. However, isoperistaltic graft reconstruction should be considered more suitable and more preferable for reconstruction. As reported, the acid regurgitation

Table 1: Types of colon graft.

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

and risk of aspiration were significantly more important in the antiperistaltic reconstruction [16-20]. Considering the risk of such complication associated with antiperistaltic reconstruction, isoperistaltic reconstruction should therefore be employed whenever possible. Currently the peristaltic reconstruction is performed as a standard procedure at most institutions [21-32]. The completion of colon reconstruction requires more time to achieve the procedure as compared to gastric reconstruction. Because of colon mobilization and need of multiple anastomoses. Colon reconstruction is s surgical procedure with high risk of surgical complications and surgeons should be familiar with such technique.

Surgical technique

The surgical technique is not described in details because the surgical methods used to mobilize the colon for use as an esophageal substitute have not changed appreciably since their initial description. Most authors prefer to use a left or extended left colon graft based on the left colic vessels and ileocolic graft based on the right colic artery. As mentioned earlier, colon segments based on the middle colic or ileocolic colic vessels can be used. Preoperative assessment of the colon is imperative before surgery for patient for whom a colon interposition was planned. Colonoscopy is performed to explore colon for any colonic pathology that might preclude its use. CT angiography may be indicated to evaluate the vasculature [15,33-36] and is very was helpful in outlining the vascular arcade of the intestinal segment to be interposed. The mechanical bowel preparation is so performed 48 hours before time of surgery.

The colon segment should be selected very carefully after detailed observation of the arterial anatomy by mesentery transillumination. 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. Therefore the proposed length of colon segment is isolated, mobilized based on its segmental vascular arcade, and the marginal arterial arcade of Drummond preserved. The final decision regarding the suitability of a colon graft is made intraoperatively, after the vasculature is dissected and inspected. The adequacy of blood supply to the future graft is assessed by palpation of pulsatile blood flow in the graft vessels, intraoperative Doppler confirmation of flow in fatty mesentery, and simulation of complete vascular isolation using atraumatic vascular clamping test, in order to reduce risk of potential arterial insufficiency [10,19]. Only at this point after good adequacy of blood supply, the colon segment selected is actually harvested for use. If an arterial insufficiency is noted and confirmed by absence of palpable pulsation, an alternative solution should be considered by performing a supercharge technique or a staging procedure to improve arterial inflow, or re-selecting another colon segment or organ. 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 [37,38]. The left colon is preferred to the right, because of its thicker wall, smaller diameter, and greater ability to propel a solid food bolus. However, the right colon has a more variable arterial anatomy and is more vulnerable to ischemia of the proximal portion.

The most direct route of reconstruction poses the least threat to the integrity of the graft vascular feeding pedicle. Most surgeons prefer using the posterior mediastinum to pull up the graft because the posterior mediastinum is the shortest and most direct route, thereby relaxing tension to the cervical anastomosis site and reducing thus the kinking and twisting risk of graft vascular pedicle [39]. However, this route has a high rate of mortality if graft necrosis or intrathoracic leak occurs. The second alternative route is the substernal space. The biggest disadvantage of the substernal approach is the potential 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. To prevent this event, some surgeons suggested enlarging the thoracic inlet by removing the left half of manubrium and the internal third of clavicle [6,10,33,19,40-42]. This procedure allows the easy access to the left internal thoracic vessels which can be useful for supercharge of graft by performing microvessel anastomosis. Other options include the transpleural and subcutaneous routes. The subcutaneous path is used only as a last resort in extreme circumstances. The transpleural route risks the disastrous results of intrathoracic leak.

To avoid redundancy of the colon graft in the thorax, the diaphragmatic hiatus must be tightened once the redundant graft is pulled down into the abdomen. The straightness of the graft is primordial parameter, so it is so important to select a graft with adequate length avoiding excess in graft length which can lead to redundancy. The goals of reconstruction are to avoid tension, rotation, kinking, or mechanical obstruction of the vascular pedicle. Regardless of the route used for reconstruction, it is important to take care of checking constantly the position of the graft vessels to ensure there is no mechanical compression, kinking or twisting that may impair the vascular supply of the graft, and to select a graft with sufficient length avoiding thus tension at the anastomotic site. As confirmed by findings, graft necrosis usually results from obstruction of the vascular pedicle. The colon reconstruction remains a surgical procedure with high risk of surgical complications. Thus it is essential to be familiar with this technique than even before to decrease the associated mortality and morbidity. Performed by experienced surgeon, colon 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.

Graft necrosis

The esophageal reconstruction by colon graft should be recognized as a surgical procedure with relatively high risk of surgical complications. Graft necrosis constitutes the most disastrous complication of colon interposition. This complication is associated with an operative mortality greater than 90% in absence of early diagnosis and adequate management [8,24,35,36,43,44]. Compared to gastric graft, a slightly higher rate of ischemic necrosis of colon graft has been reported by authors. The cervical portion of transposed colon graft is farthest from the vascular supply and thus is at highest risk of ischemic necrosis. As reported by Gaissert and colleagues, [8], the incidence of graft necrosis seems to be less if a short segment colon is used rather than long-segment grafting. Raffensperger and colleagues, [45] reported that the graft necrosis rate using colon grafting in children is similar to that in adults. Moorehead and Wong, [46] reported an incidence of colon graft necrosis of 13% and identified the use of the subcutaneous route was a risk factor for the development of graft necrosis. Davis and colleagues, [21] who had a preference for the right colon reported, in patients who received either gastric or colonic transposition for esophageal reconstruction, an incidence of graft necrosis of 2.4% in right colon interposition which was not statistically significant compared to gastric graft necrosis (0.5%). Briel and colleagues, [47] reported, in 393 patients who underwent either gastric or colon reconstruction after esophagectomy, a colon graft necrosis of 7.4%.

The risk factors identified were hypertension, reduced cardiac contractility, and chronic obstructive pulmonary disease which were significantly associated with the development of graft necrosis. These comorbidity factors carry an increased risk of graft necrosis caused by compromised tissue perfusion and oxygenation. On other hand, De Meester et al, [13] reported a rate of 4.7% of intraoperative graft ischemia after left colon interposition. Whereas Boukerrouche, [19] reported, in a large series of 105 patients who underwent a substernal left colon interposition, a graft necrosis rate of 1.9%. The necrosis was located to the proximal portion of the graft and the cause was venous insufficiency caused by graft compression at the level of thoracic inlet [19]. So, the incidence of graft necrosis have been decreased over the time [8,10,19,21,23,36,45,47-52] (Table 2). This decrease is explained by significant improvement of operative technique and perioperative management. As previously reported, the incidence of graft necrosis is slightly higher in right colon interposition than that in left colon grafting. After graft necrosis, the difficulty is how to complete further digestive re-reconstruction which requires a panel of complex surgical procedures. Therefore, the best way is the prevention based on preoperative identification of risk factors and acquisition of surgical skills.

DIAGNOSIS AND MANAGEMENT

The clinical manifestation of necrosis may be fulminant but is often nonspecific. Sepsis, persistent high fevers, unexplained tachycardia, unexplained leukocytosis, hemorrhagic nasogastric tube drainage should prompt an assessment of graft vitality. Venous congestion presents more insidiously, with hemorrhagic infarction and graft mucosal bleeding identified by bloody enteral drainage tube output. A high index of suspicion of graft necrosis should prompt an evaluation of graft viability. Early diagnosis and prompt adequate treatment offers the best opportunity to save the patient life. Endoscopic examination is used to confirm the diagnosis. Mucosal discoloration with adherent mucus that cannot be removed with irrigation, and clearly demarcated, ulcerated mucus as are suggestive of graft necrosis. As disastrous as this complication is, it is even worse to miss the diagnosis. In presence of unexplained symptoms, blood anomalies and suspicion of necrosis, it is worthy to consider surgical exploration to verify graft viability visually. When the esophagocolic anastomosis is located at the neck, it is easy to visually inspect the cranial part of graft. If the graft tip is found to be viable, it is unlikely that the more proximal graft is ischemic. A long-segment stricture of the interposed colon graft is a late complication resulting from delayed ischemia in an occasional patient. Cheng and colleagues, [54] called this entity of ischemia without necrotic vascular insufficiency of interposed graft colon a subcute ischemia. They presented two patients in whom the developmental process of this entity was tracked radiographically. However, it was not clear whether this effect was from primary arterial or venous insufficiency. Once diagnosed, colon graft necrosis should be treated with prompt re-exploration, resection of the necrotic colon part, mediastinal or substernal space drainage, proximal diverting cervical esophagostomy, feeding gastrostomy or jejunostomy for enteral nutritional support and broad-spectrum antibiotics. Unless the necrotic portion is very limited, the colon graft is completely taken down from the chest or substernal space and resected or returned to the abdomen. The decision for immediate restoration of esophagointestinal continuity depends on the overall condition of the patient, the presence of local sepsis, and the availability of alternative conduits. However, most authors advocate delaying construction for 3 to 6 months.

Table 2: Colon graft necrosis.

Author	year	No. of patients	Necrosis (%)
Isolauri [49]	1987	248	3
DeMeester [10]	1988	92	3.4
Cerfolio [8]	1995	32	6.2
Mansour [46]	1997	101	3
Thomas [23]	1997	60	5
Wain [36]	1999	52	9.6
Hagen [51]	2001	72	5.6
Fürst [52]	2001	53	3.8
Davis [21]	2003	42	2.4
Briel, et al. [48]	2004	163	7.4
Shirakawa [50]	2006	51	0
Boukerrouche [19]	2016	105	1.9

RISK FACTORS

The most commonly graft necrosis cause is technical mismanagement of the vascular feeding pedicle, caused by inadequate exposure; excessive traction, graft twisting, or kinking of the pedicle during the graft pull up through reconstruction route [44,54]. Vascular abnormalities, obstructing atherosclerotic vascular disease and insufficient venous drainage also contribute to graft necrosis [23,54,55]. Operative or perioperative hypotension may also induce an arterial spasm and initiate a cascade of vascular stasis, thrombosis, ischemia, and necrosis. The preexisting comorbidities such as diabetes, hypertension, low cardiac output, and obstructive pulmonary disease are the final risk factors of necrosis.

PREVENTION

The esophageal reconstruction by colon graft should be recognized as a surgical procedure with relatively high risk of surgical complication. Once, graft necrosis occurred; it is no reversible, so prevention is the best way to minimize the risk. Therefore there are three principle precautions to minimize the graft risk necrosis during colon interposition. The first is, identification of patient risk factors (comorbidities), a careful preoperative evaluation of the colon and its blood supply as described previously. The second is to use meticulous operative techniques in the preparation, handling, and passage of the colon graft through the reconstruction route particularly when the substernal space is used. Graft ischemia is often identified intraoperatively and confirmed by absence Doppler signal of flow in the vascular arcade of graft [22,26,45]. The causes of graft ischemia are arterial insufficiency or venous stasis of a long-segment graft and intraoperative injury to the arterial supply or venous drainage of the graft [55]. The third is to use vascular augmentation techniques to optimize arterial and venous blood flow to the graft. As reported by authors, there is clearly an advantage to prevent graft necrosis by adding vascular supercharge [24,27,35,48]. Adding microvessel anastomosis should be considered whenever it is necessary and imperative. Therefore, patients who showed intraoperative graft ischemia, adding microvessel anastomosis became necessary to salvage the colon graft. However, performing a supercharge of graft is a procedure which requires a longer operative time. 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. Golshani and colleagues, [56] presented a case report of a patient who received a right colon interposition and after pull up of graft to the neck, the cecum had became congested, cyanotic, with absent peristalsis and Doppler signal. The transverse cervical artery and the internal jugular vein were anastomosed to the graft mesenteric vessels resulting of immediate clearance of congestion and cyanosis, as well as vigorous peristalsis [49]. O'Rourke and Threlfall, [57] performed in 14 patients a microvascular reinforcement of colon graft using the transverse cervical artery and external jugular vein. There were no cases of graft necrosis or anastomotic leakage among the patients. Identification of patient risk factors, preoperative evaluation of the colon and meticulous operative technique are the best defenses against conduit ischemia. Graft supercharge should be used whenever necessary.

CONCLUSION

The colon is the first abdominal digestive organ used as an esophageal substitute. Its mesenteric vascular anatomy is ideal to use it as a graft based on its isolated mesenteric pedicle. The key point of a successful esophageal reconstruction is to ovoid cervical anastomosis tension by using an optimal graft with sufficient length, good blood supply and good venous drainage. Regardless of the reconstruction route, the blood supply to the graft is the most important factor affecting directly the surgical outcome. Therefore, the selection of an optimal colon graft should be made very carefully based on the examination of mesentery vascular anatomy and evaluation of the blood supply quality. Colon reconstruction is relatively a high risk procedure and it is necessary for surgeon to be familiar with this surgical technique. Graft necrosis is disastrous complication which affects greatly the surgical outcome. The difficulty is how to complete further digestive re-reconstruction which requires a panel of complex surgical procedures. Necrosis risk factors are related to graft length, comorbidities, and operative technique. Therefore, A careful preoperative assessment of the colon, knowledge of patient comorbidities and meticulous surgical technique are the best defenses against graft necrosis.

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