Diagn Interv Radiol 2012; 18:314–318

INTERVENTIONAL RADIOLOGY
ORIGINAL ARTICLE

Role of preoperative angiography in colon interposition surgery

Shaunagh McDermott, Amy Deipolyi, Thomas Walker, Suvranu Ganguli, Stephan Wicky, Rahmi Oklu

PURPOSE
The aim of this study was to evaluate the role of preoperative angiography in patients undergoing colonic interposition.

MATERIALS AND METHODS
We searched the electronic database of our radiology department for the term "mesenteric angiography" over a 10-year period from January 1, 2001 to December 31, 2010.

RESULTS
We identified 54 patients who had undergone mesenteric angiography before esophageal reconstruction, 16 of whom proceeded to have colonic interposition surgery. One patient (6.3%) developed graft necrosis, two (12.5%) developed an anastomotic leak, and three (18.8%) developed an anastomotic stricture. These complication rates are similar to those reported in the surgical literature for patients who did or did not undergo routine preoperative angiography.

CONCLUSION
There is no significant difference in the rates of complications secondary to ischemia (graft necrosis, anastomotic stricture, and anastomotic leak) in patients who undergo routine preoperative angiography as compared with those who do not.

Key words: • *angiography* • *surgical anastomosis* • *colon* • *esophageal neoplasms*

From the Division of Vascular Imaging and Interventions, Department of Radiology (R.O. ✉ *roklu@partners.org*), Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts, USA.

Received 13 August 2011; revision requested 22 August 2011; revision received 11 September 2011; accepted 18 September 2011.

Published online 4 January 2012
DOI 10.4261/1305-3825.DIR.4986-11.1

The surgical use of the colon as an esophageal substitute plays an important role in esophageal reconstruction, especially when the stomach is unavailable for use. Colonic interposition may be the only surgical option in various situations, such as when prior gastric surgery precludes use of the stomach; when total gastrectomy accompanies esophageal resection; or as a salvage procedure when previous gastroplasty fails. The advantages of using the colon include its length, acid resistance, and typically rich blood supply. The disadvantages, as compared with gastric pull-up surgery, include the long operating time caused by mobilization of the colon and an additional anastomosis, both of which increase the risk of complications (1).

The preservation of an adequate blood supply is one of the most important factors governing the success of colonic interposition grafts. Graft ischemia and anastomotic breakdown, two of the most serious and potentially lethal complications, are both typically related to arterial or venous insufficiency of the interposed segment. Thus, some investigators recommend preoperative angiography to evaluate the vascular supply of the proposed conduit as a means of reducing complications related to compromised blood supply (2).

The routine use of preoperative angiographic assessment of the colonic arterial supply is controversial, but some institutions use it to assess arterial patency. Additionally, preoperative angiography can be used to identify an anomalous or aberrant vascular supply to the colon, and thereby guides the selection of reconstruction options. The aim of this study was to report our experience with preoperative angiography in patients being evaluated for esophageal reconstruction and to compare our findings with previously reported results. Specifically, we examined the utility of preoperative angiography to the surgeon.

Materials and methods

This retrospective study was compliant with the US Health Insurance Portability and Accountability Act and was approved by our Institutional Review Board with a waiver of informed consent. Using the search term "mesenteric angiogram," we performed a search of the radiology electronic database at our institution, which contains over 10 million studies. We limited our search to a 10-year period, from January 1, 2001 to December 31, 2010. We included all patients who had undergone angiography before esophageal reconstruction. We identified 54 patients who fulfilled our search criteria: 41 male patients and 13 female patients with a mean age at the time of esophageal reconstruction of 58.6 years (range, 26–80 years). Two interventional radiologists reviewed the images from each study.

The diagnostic angiograms in the study were performed following standard protocols. The patient is placed on the angiographic table in

the supine position. Typically, the right common femoral artery is accessed using an 18-gauge needle, which is then exchanged over a 0.035-inch wire with a 5 F×10 cm vascular sheath. Next, the celiac artery, superior mesenteric artery (SMA), and inferior mesenteric artery (IMA) are often accessed in a sequential manner. Digital subtraction angiography is occasionally performed in multiple obliquities to better define the vascular anatomy when necessary. Typically, a Cobra catheter is sufficient for catheterizing the mentioned arteries; however, other reverse-curved catheters, such as a Simmons catheter, are sometimes necessary. The angiograms are evaluated in detail to document any evidence of variant or abnormal vascular anatomy and atherosclerosis.

Results

During the study period, 54 patients underwent mesenteric angiography before esophageal reconstruction. Twelve patients underwent surgery for benign causes and 42 patients underwent surgery for malignant causes. Twenty-six patients had undergone previous esophageal or gastric surgery; one patient had prior abdominal aortic aneurysm repair and four patients had a history of prior colonic surgery.

On angiography (Table 1), 19/54 (35%) patients had vascular anatomy that was considered unsuitable for left colonic interposition surgery. The angiographic findings considered unsuitable for left colonic interposition included the following:

1) inadequate anastomosis between the left branch of the middle colic artery and the ascending branch of the left colic artery (n=9),
2) two middle colic arteries (n=2),
3) non-visualization of the right colic artery, middle colic artery, and IMA (n=2, each),
4) common origin of the right and middle colic arteries (n=1), and
5) pseudoaneurysm of the SMA (n=1).

Angiographic vascular anatomy was considered suitable (35/54, 65%) if it fulfilled the five criteria described by Peters et al. (2) as crucial to the successful use of the left colon as an esophageal conduit:

1) a patent IMA,
2) a visible ascending branch of the left colic artery,
3) a well-defined anastomosis between the middle and left colic systems,
4) a single middle colic trunk before its division into the right and left branches, and
5) separate origin of the right colic artery.

Of the 54 patients (Table 2), 4 did not undergo surgery because of clinical disease progression and were excluded from further analysis. Thirty-four of these 50 remaining patients did not undergo colonic interposition surgery for various reasons. Specifically, they were either found to be inoperable at the time of surgery (n=7), or underwent jejunal interposition (n=4), esophagogastrectomy (n=13), gastropharyngostomy (n=2), esophagojejunostomy, gastrojejunostomy, partial resection of the esophagus, hiatus hernia repair, dilatation, pectoralis major muscle flap repair, or gastrostomy (n=1, each). One patient with thyroid cancer did not require esophageal surgery.

The 16 remaining patients who underwent esophageal replacement surgery had colonic interposition surgery. These patients all had suitable angiographic anatomy for left colonic interposition; however, in one case, the left colon was not viable after a clamping trial due to venous congestion and the surgeon performed a right colonic interposition instead.

Of the patients who underwent colonic interposition surgery following angiography, six had no surgical complications. One (6.25%) had an anastomotic leak with necrosis requiring resection and formation of a cervical esophagostomy and two (12.5%) had anastomotic leaks without evidence of necrosis and were managed conservatively. One of

Table 1. Angiographic findings

	Number of cases (%)
Suitable anatomy based on findings by Peters et al. (2)	35 (64.8)
Inadequate anastomosis between right branch of middle colic and ascending branch of left colic arteries	9 (16.7)
Two middle colic arteries	2 (3.7)
Non-visualization of the right colic artery	2 (3.7)
Non-visualization of the middle colic artery	2 (3.7)
Non-visualization of the IMA	2 (3.7)
Common origin of the right and middle colic artery	1 (1.9)
Pseudoaneurysm of the SMA	1 (1.9)

IMA, inferior mesenteric artery; SMA, superior mesenteric artery.

Table 2. Surgery types

	Number of cases
Colon interposition	16
Inoperable at time of surgery	7
Jejunal interposition	4
Esophagogastectomy	13
Gastropharyngostromy	2
Esophagojejunostomy	1
Gastrojejunostomy	1
Partial resection of the esophagus	1
Hiatus hernia repair	1
Esophageal dilatation	1
Pectoralis major muscle flap	1
Gastrostomy	1
No esophageal resection	1
Did not proceed to surgery	4

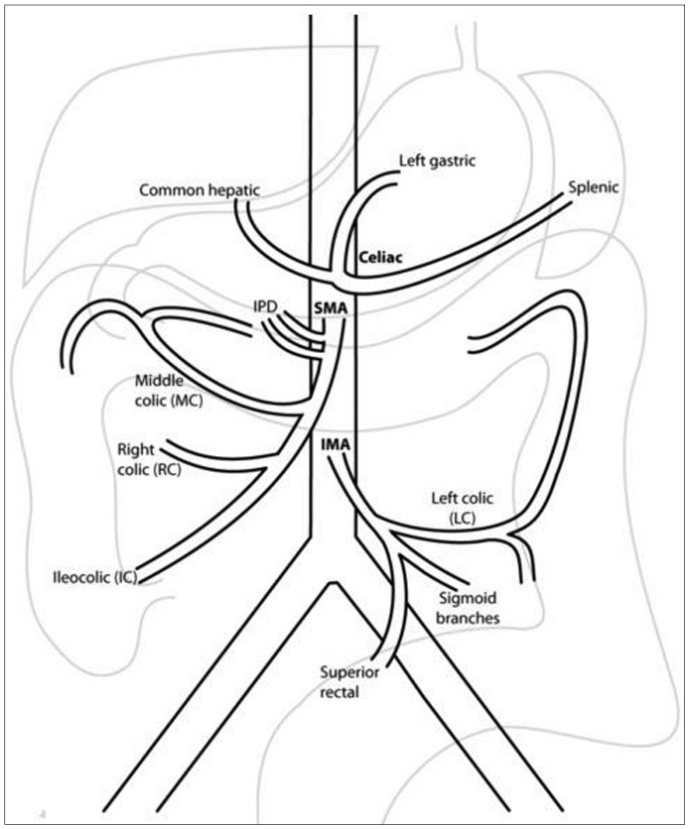

Figure 1. Classical blood supply to the colon. SMA, superior mesenteric artery; IMA, inferior mesenteric artery.

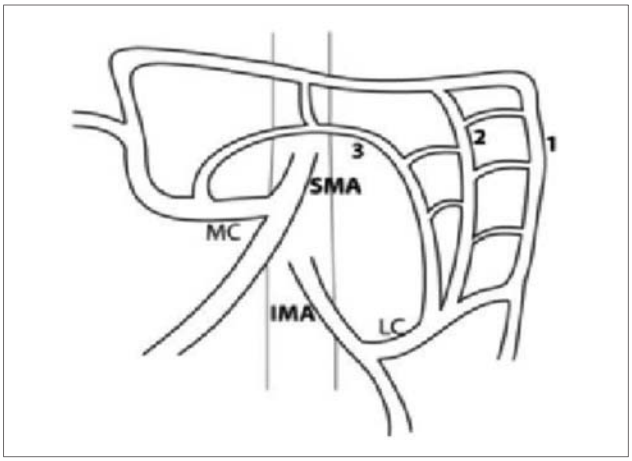

Figure 2. Collateral blood supply between the superior mesenteric artery and inferior mesenteric artery. 1, marginal artery of Drummond; 2 and 3, arc of Riolan. The more peripherally located collateral connection, as depicted in 3, may sometimes be referred to as the meandering artery of Moskowitz. SMA, superior mesenteric artery; IMA, inferior mesenteric artery.

these patients subsequently developed an anastomotic stricture requiring multiple dilatations. Two additional patients also had anastomotic strictures that required multiple dilatations. Other complications included a superficial stitch, fluid collection in the neck requiring drainage, anterior abdominal wall abscess, multiple episodes of small bowel obstruction secondary to adhesions, and dysphagia caused by external compression of the conduit requiring esophageal stenting (n=1, each).

Discussion

Approximately 10% of all patients who undergo esophagectomy and esophageal replacement surgery will develop conduit ischemia or an anastomotic leak, with mortality rates of 14% and 12%, respectively (3). Briel et al. (3) found that, in patients who developed clinical graft ischemia, one-third healed without complications, one-third developed a stricture without a leak, and one-third developed an anastomotic leak, of which half developed a stricture. Consequently, the combination of ischemia and an anastomotic leak significantly increases the risk of stricture. In patients who develop an anastomotic leak without ischemia, about half develop a stricture and half heal without complications (3).

An intact colonic vascular supply is essential to the success of colonic interposition surgery, whereas a compromised vascular supply may contribute to graft ischemia. The blood supply to the colon is derived from branches of the SMA and IMA (Fig. 1), with the former supplying the right colon (cecum, ascending colon, hepatic flexure, and proximal transverse colon). In <1% of cases, the SMA origin is fused with the celiac artery, creating a celiacomesenteric trunk (4). A common origin of the SMA and one or more of the main branches of the celiac trunk is present in 7% of cases, but it involves the splenic artery in about 1% of cases (5).

Angiographic patterns of the SMA anatomy have been divided into five categories based on the work of Sonneland et al. (6). Type 1 consists of patients with the most common, classical arterial configuration, consisting of three dominant branches supplying the right colon: the middle colic, right colic, and ileocolic arteries. Patients with an absent right colic artery are classified as type 2, and patients with an absent middle colic artery as type 3. Type 4 is characterized by multiple right colic arteries and type 5 patients show multiple middle colic arteries. Multiple variations in the middle colic artery have been described, including an aberrant origin, complete absence (in up to 25% of individuals), and presence of an accessory or double middle colic artery (~10%) (7). The right colic artery shows the greatest variation among the colic arteries. It directly arises from the SMA in about 40% of individuals, from the middle colic in 30%, the ileocolic in 12%, and may be absent in about 20% (7).

The arterial supply to the left colon is from the IMA by means of its left colic and sigmoid branches. There are three branching patterns of the left colic artery (4). In type 1, the left colic artery arises from the IMA; in type 2, the left colic and the first sigmoidal artery have a common trunk; and in type 3, the left colic and first sigmoidal arteries arise simultaneously from the IMA.

The mesenteric circulation has a rich system of collateral vessels (Fig. 2) that provide a potential mechanism for maintaining adequate perfusion to the colon when major mesenteric branches are surgically ligated. These collaterals, which play an important role in colonic surgery, are those between the SMA and IMA, and primarily include the marginal artery of Drummond (8) and the arc of Riolan (9) (Fig. 3). The meandering artery of Moskowitz represents an

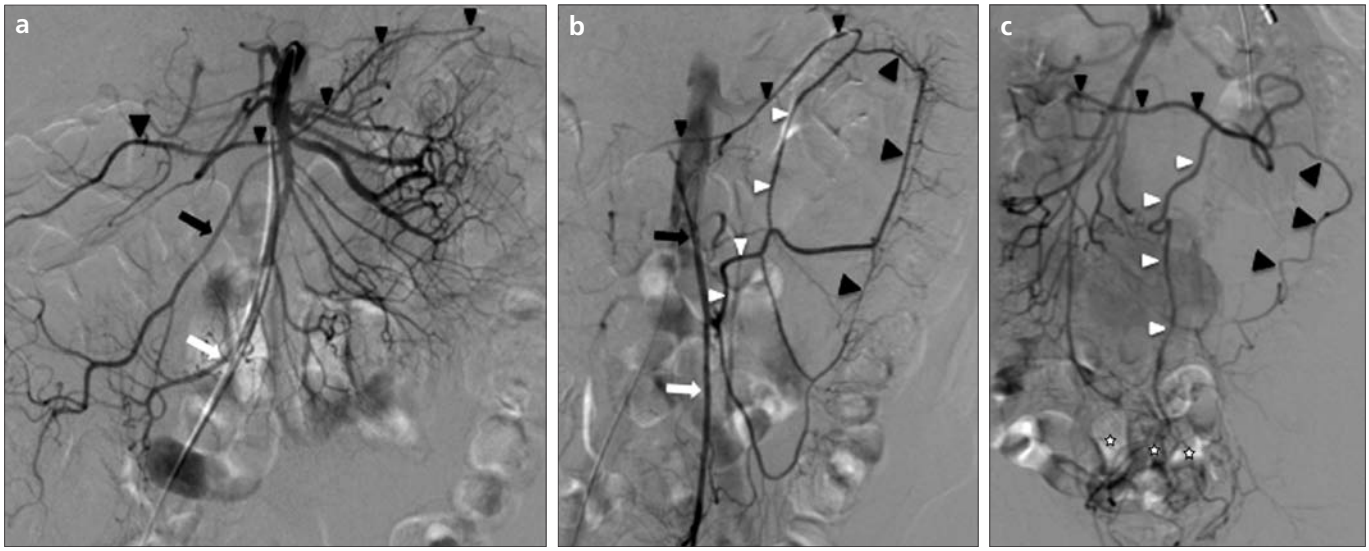

Figure 3. a–c. Selective superior mesenteric artery (SMA) arteriogram showing the middle colic artery dividing into the right branch *(large black arrowhead)* and left branch *(small black arrowhead)* **(a)**. The right colic artery *(black arrow)* and ileocolic artery *(white arrow)* are also labeled. Selective arteriogram where the inferior mesenteric artery (IMA) origin *(black arrow)* branches into the left colic artery and terminal branch of the IMA, which is the superior rectal (hemorrhoidal) artery *(white arrow)* **(b)**. The ascending branch of the left colic artery *(white arrowheads)* anastomoses with the left branch of the middle colic artery *(small black arrowheads)* near the splenic flexure. The continuous marginal artery of Drummond *(large black arrowheads)* courses along the mesenteric border of the colon supplying the vasa recta. Selective SMA arteriogram demonstrates an arc of Riolan *(white arrowheads);* inferiorly, branches of the superior rectal artery are opacified *(white asterisks),* and superiorly, its connection to the left branch of the middle colic artery *(small black arrowhead)* is seen **(c)**. *Large black arrowheads* indicate the marginal artery of Drummond.

additional collateral pathway between the SMA and IMA (Fig. 2); however, some controversy exists regarding the true origin of the meandering artery of Moskowitz, because some believe that it represents a dilated arc of Riolan, whereas others believe that it is a separate discrete anastomotic channel. The meandering artery of Moskowitz courses along the base of the colonic mesentery and represents a connection between the proximal segment of the middle colic artery and the ascending branch of the left colic artery (10).

The marginal artery of Drummond is the major collateral arcade between the SMA and IMA, is located within the mesentery of the colon, and lies about 2–3 cm from the mesenteric border of the bowel supplying the vasa recti (Fig. 3b and 3c). This collateral arcade is composed of branches from the ileocolic and right, middle, left colic, and sigmoidal arteries. The marginal artery is usually a continuous vessel that runs parallel to the colon; it is better developed in the left colon and is inconsistent or poorly developed in the right colon in 25%–75% of patients (8). There are two watershed points: the Griffiths' point at the splenic flexure where branches of the middle and left colic artery meet, and the less important Sudek's point at the rectosigmoid junction where the last sigmoid branch and the superior hemorrhoidal artery meet. The arc of Riolan (Fig. 3c) represents a set of collateral branches located centrally within the mesentery and forms a communication between the middle colic and left colic arteries in a region that usually does not have major branches. It is present in 7%–10% of the population (9).

Our study showed that 65% of patients demonstrated suitable anatomy for left colonic interposition, which is less than the 84% reported by Peters et al. (2). In addition, we found that the middle colic artery is absent in 3.7% of patients, an incidence much less than the 8%–25% incidence previously reported (6, 7). Similarly, the incidence of other anatomic anomalies excluding colonic interposition surgery was also decreased as compared with prior reports. These anomalies included double middle colic arteries (3.7% vs. 10%–12%), absence of the right colic artery (3.7% vs. 20%), and common origins of the right and middle colic arteries (1.9% vs. 30%) (6, 7). The lower incidence of anatomical variants in our study population is probably due to our small cohort number.

Patient follow-up ranged from 1 to 62 months, with a mean follow-up of 19.3 months. Our postsurgical complication rates of graft necrosis (6.2%), anastomotic leak (12.5%), and anastomotic stricture (18.7%) were similar to those previously reported (Table 3) (1, 3, 11–20) Of these studies, five (including ours) routinely used preoperative angiography in all or a defined select group of patients, two did not use routine preoperative angiography, and six did not report whether preoperative angiography was used. The rate of graft necrosis ranged from 3% to 5% in those who did not routinely perform preoperative angiography; 3% to 9.6% in those who did perform angiography in all or a predefined select group of patients; and 0% to 9% in those who did not report if they did or did not perform angiography. The rate of anastomotic leak ranged from 4% to 10%, 3.3% to 14.8%, and 0% to 30%, and the anastomotic stricture rates were 13.5%, 2.3%–24%, and 4.5%–19% in each of these respective groups. It is likely that a greater number of colonic interposition surgeries are performed at our institution because preoperative angiography is not the standard practice. Therefore, the extent to which complications secondary to ischemia arise from aberrant vascular anatomy and vascular disease is unclear. In cases where preoperative angiography was not performed, computed tomography (CT) angiography studies may have been performed for evaluation of the mesenteric

Table 3. Published studies describing colon interposition as an esophageal substitute

Study	Number of patients	Preoperative angiography	Preferred method (% of procedures)	Graft necrosis (%)	Anastomotic leakage (%)	Anastomotic stricture (%)
Wain et al. 1999 (1)	52	Preoperative angiography in 32 patients	Left (88.5)	9.6	5.8	23.1
Briel et al. 2004 (3)	163	DNR	DNR	7.4	6.1	8.7
Klink et al. 2010 (11)	43	DNR	Left (58)	9	30	19
Davis et al. 2003 (12)	42	DNR	Right (66.7)	2.4	14.3	19
DeMeester et al. 1998 (13)	92	58 patients had preoperative angiography	Left (92)	7.6	4.3	4.3
Hagen et al. 2001 (14)	72	DNR	Left	5.6	12.5	DNR
Mansour et al. 1997 (15)	129	Age ≥60 years with prior intestinal resection and PVD	Right (66)	3	14.8	2.3
Cerfolio et al. 1995 (16)	32	Patients with PVD or repair of a AAA (n=5)	Left (63)	9.4	3.3	24
Isolauri et al. 1987 (17)	248	None	Left (54)	3	4	DNR
Thomas et al. 1997 (18)	60	None	Left (88)	5	10	13.5
Kolh et al. 2000 (19)	38	DNR	Left (63)	0	0	DNR
Knezevic et al. 2007 (20)	336	DNR	Left (76.7)	2.4	10.1	4.5

DNR, data not reported; PVD, peripheral venous disease; AAA, abdominal aortic aneurysm.

vasculature. Cases where only CT angiography was performed before colonic interposition surgery were not captured from our departmental database using the search terms selected.

A limitation of our study is the small number of patients who underwent colonic interposition (n=16); however, when we include all of the studies analyzed in this paper, there were 308 patients in the group where routine angiography was performed, 321 in the group where angiography was performed in all or a predefined select group of patients, and 694 in the group where routine angiography performance was not reported.

In conclusion, there is no significant difference in the rates of complications secondary to ischemia (graft necrosis, anastomotic stricture, and anastomotic leak) in patients who undergo routine preoperative angiography as compared with those who do not.

Conflict of interest disclosure

The authors declared no conflict of interest.

References

1. Wain JC, Wright CD, Kuo EY, et al. Long-segment colon interposition for acquired esophageal disease. Ann Thorac Surg 1999; 67:313–317.
2. Peters JH, Kronson JW, Katz M, DeMeester TR. Arterial anatomic considerations in colon interposition for esophageal replacement. Arch Surg 1995; 130:858–862.
3. Briel JW, Tamhankar AP, Hagen JA, et al. Prevalence and risk factors for ischemia, leak, and stricture of esophageal anastomosis: gastric pull-up versus colon interposition. J Am Coll Surg 2004; 198:536–541.
4. Lin PH, Chaikof EL. Embryology, anatomy, and surgical exposure of the great abdominal vessels. Surg Clin North Am 2000; 80:417–433.
5. Settembrini PG, Jausseran JM, Roveri S, et al. Aneurysms of anomalous splenomesenteric trunk: clinical features and surgical management in two cases. J Vasc Surg 1996; 24:687–692.
6. Sonneland J, Anson BJ, Beaton LE. Surgical anatomy of the arterial supply to the colon from the superior mesenteric artery based upon a study of 600 specimens. Surg Gynecol Obstet 1958; 106:385–398.
7. Sakorafas GH, Zouros E, Peros G. Applied vascular anatomy of the colon and rectum: clinical implications for the surgical oncologist. Surg Oncol 2006; 15:243–255.
8. Krupski WC, Selzman CH, Whitehill TA. Unusual causes of mesenteric ischemia. Surg Clin North Am 1997; 77:471–502.
9. Michels NA, Siddharth P, Kornblith PL, Parke WW. The variant blood supply to the descending colon, rectosigmoid and rectum based on 400 dissections. Its importance in regional resections: a review of medical literature. Dis Colon Rectum 1965; 8:251–278.
10. Moskowitz M, Zimmerman H, Felson B. The meandering mesenteric artery of the colon. Am J Roentgenol Radium Ther Nucl Med 1964; 92:1088–1099.
11. Klink CD, Binnebosel M, Schneider M, Ophoff K, Schumpelick V, Jansen M. Operative outcome of colon interposition in the treatment of esophageal cancer: a 20-year experience. Surgery 2010; 147:491–496.
12. Davis PA, Law S, Wong J. Colonic interposition after esophagectomy for cancer. Arch Surg 2003; 138:303–308.
13. DeMeester TR, Johansson KE, Franze I, et al. Indications, surgical technique, and long-term functional results of colon interposition or bypass. Ann Surg 1988; 208:460–474.
14. Hagen JA, DeMeester SR, Peters JH, Chandrasoma P, DeMeester TR. Curative resection for esophageal adenocarcinoma: analysis of 100 en bloc esophagectomies. Ann Surg 2001; 234:520–530.
15. Mansour KA, Bryan FC, Carlson GW. Bowel interposition for esophageal replacement: twenty-five-year experience. Ann Thorac Surg 1997; 64:752–756.
16. Cerfolio RJ, Allen MS, Deschamps C, Trastek VF, Pairolero PC. Esophageal replacement by colon interposition. Ann Thorac Surg 1995; 59:1382–1384.
17. Isolauri J, Markkula H, Autio V. Colon interposition in the treatment of carcinoma of the esophagus and gastric cardia. Ann Thorac Surg 1987; 43:420–424.
18. Thomas P, Fuentes P, Giudicelli R, Reboud E. Colon interposition for esophageal replacement: current indications and long-term function. Ann Thorac Surg 1997; 64:757–764.
19. Kolh P, Honore P, Degauque C, Gielen J, Gerard P, Jacquet N. Early stage results after oesophageal resection for malignancy – colon interposition vs. gastric pull-up. Eur J Cardiothorac Surg 2000; 18:293–300.
20. Knezevic JD, Radovanovic NS, Simic AP, et al. Colon interposition in the treatment of esophageal caustic strictures: 40 years of experience. Dis Esophagus 2007; 20:530–534.