Substantiation of Colon: Interposition for Esophageal Replacement with Vascular Augmentation for Oncological Patients

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In our work we have been developing and improving esophageal replacement in cases with extensive esophageal cancer. The new method involves interposition with vascular augmentation of a colonic graft, including the distal one-third of the ascending colon, the right angle and proximal two-thirds of the ascending colon. An anatomical sectional study was carried out on 25 adult corpses. Internal thoracic vessels as a source of blood supply and middle colic vessels as the vascular pedicle were used for vascular augmentation. The work served as prototype for colon interposition in oncological patients with esophageal diseases. Options for vascular augmentation have been developed. The new method was carried out on 9 male patients, 6 with esophageal cancer and 3 with gastroesophageal cancer of average age 61.0 (53-64) years. They underwent repeated (5) or delayed (4) esophageal replacement. The left internal thoracic artery was used as an additional blood supply source, anastomosed with the middle colic artery in all 9 patients. Additional intervenous anastomoses were performed in 3 patients. The operative time was 5-7 h. Intraoperative blood loss was 300 (175-375) ml. Post-operative complications included partial cervical esophageal anastomotic leak in 1 patient. In-hospital stay was 23 (22-31) days. One-year survival rate was 67±16%, median survival 16±0.2 (95% CI 15.5–16.5) months.

Keywords: esophageal cancer, colon interposition, vascular augmentation

Introduction

Over the past 50 years, a large number of experimental and clinical studies have been carried out to find new ways of improving graft blood supply and preventing ischemic complications following esophageal replacement. Currently used methods of increasing artificial esophagus viability are very diverse; in some cases, vascular augmentation of the colon graft avoids ischemic complications, such as anastomotic leakage and/or graft necrosis [1].

The actual trend of esophageal reconstructive surgery is by way of perioperative prophylaxis and prevention of ischemic complications. The most common option is a one-stage esophageal reconstruction with stomach tissue, but not where the stomach is compromised. Esophageal replacement by colon interposition is the best option for long-segmental reconstruction in the case of plastic material shortage. The success of using colon as an esophageal substitute depends on the adequacy of its blood supply, sometimes requiring vascular enhancement. These procedures are called supercharge and superdrainage techniques that form the basis of vascular augmentation [2-5]. Due to the recent rapid development of microsurgical techniques, it has been expedient to implement esophageal replacement using different visceral grafts with additional blood supply. Vascular reinforcement in esophageal replacement helps prevent ischemic complications and increases blood delivery to the interposed colon [6].

We have tried to improve the results of esophageal replacement by developing a new method of colon interposition as mentioned above. Development of the new method actually began with an anatomical study on 25 adult corpses with no history of gastrointestinal tract diseases (20 men and 5 women, aged from 45 to 81 (average 68) years. Anatomical features of the colic vessels were examined that were used as vessels for supercharge and super-drainage. The abdominal cavity was dissected and the colon mobilized in a subtotal way to the left corner. The ascending colon was transected between 2 ligatures. During dissection of the colon middle colic vessels were isolated, and their length and diameters measured (including the total length of the vascular pedicle to its ramifications). Middle colic vessels were transected and colon mobilization was continued to the left corner, forming a graft on the vascular pedicle with the left colic vessels (figure 1).

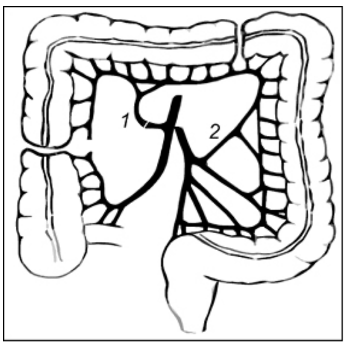

Figure 1 *Graft mobilization scheme (1 — middle colic artery, 2 — left colic artery)*

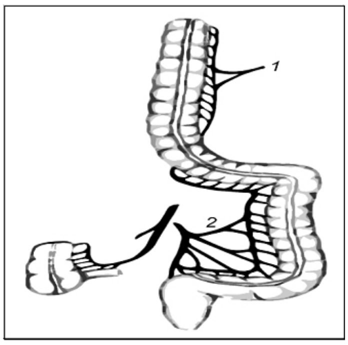

Figure 2 *Graft translocation scheme (1 — middle colic artery, 2 — left colic artery)*

Accessory middle colic arteries were preserved, if present, and used as a part of vascular pedicle together with left colic artery. The colonic graft after formation was raised to the level of left mandible angle (figure 2). Its length (38-40 cm) and the distance from this reference point to the antrum were measured (the criteria of sufficient length). If the graft was longer, the highest point of its extent was marked. The graft was placed on the front surface of the rib cage and the most convenient intercostal space for vascular anastomosis with the left internal thoracic vessels identified. The colic graft was interposed to the neck by a retrosternal route. Thus its vascular mesentery was placed at the left and alongside of the stomach. For vascular anastomoses, the recipient zone by cartilaginous part was formed by resection of an appropriate rib at the level of vascular pedicle with colic vessels projection, which gave free space in the left mediastinal space needed for left internal thoracic vessel mobilization (figure 3); this made it easier to take the graft vascular pedicle from a retrosternal tunnel without any tension.

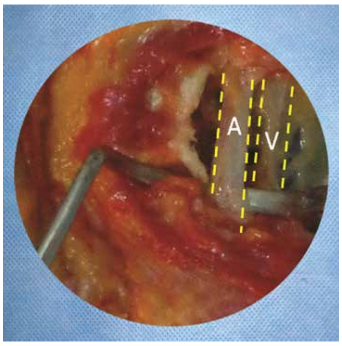

Figure 3 *Internal thoracic vessels mobilization (A — artery, V — vein)*

In the open left mediastinal space, a vascular anastomosis was made between vascular pedicle (extracted from retrosternal tunnel) with the middle colic vessels (arteries and veins) and left internal thoracic vessels (arteries and veins). The aboral end of the graft was anastomosed with the lower third of the stomach body; meanwhile we restored the colon continuity and the laparotomic wound sutured in layers. Finally, cervical esophageal anastomosis was created end-to-end between cervical esophagus and colic graft oral (the scheme is presented in figure 4).

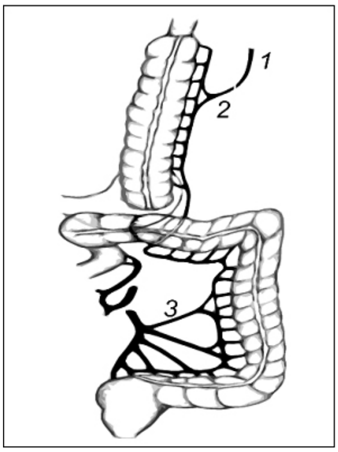

Figure 4 *Esophageal replacement by colon interposition with vascular augmentation.*
1 - internal thoracic artery, 2 - vascular pedicle with middle colic artery, 3 - the main feeding vascular pedicle with left colic artery

We found that the graft length was sufficient to cover the neck in all cases. The average graft length was 42 (41-44) cm and was significantly higher than the distance from the antrum to the left mandible angle 39 (38-40) cm ($p<0.001$). The colonic graft length could reach an extreme point at the left ear in 22 (88%) cases, and reached only the level of thyroid cartilage in 3 (12%) cases. Vascular pedicle length from the beginning of the left colic artery to the graft aboral end was 9 (8.0-9.5) cm, sufficient for free autograft movement in vertical direction to achieve the most convenient III intercostal space for vascular anastomosis formation. The left colic artery diameter was 2.6 (2.5-2.8) mm. Accessory middle colic arteries did not prevent graft translocation to the neck in 4 (16%) cases and these were saved. The accessory middle colic artery diameter had an average of 2.3 (2.1-2.5) mm, and the vascular pedicle length 6.1 (6.0-6.3) cm.

Vascular pedicle length with middle colic vessels was 6.8 (6.0-7.1) cm, convenient for vascular anastomosis without tension. The middle colic artery diameter was 2.8 (2.5-3.0) mm, and the vein 3.0 (2.9-3.0) mm. In most cases the vascular pedicle with middle colic vessels projected onto the edges of III region rib and III intercostal space – 16 cases, IV intercostal space – 6 and in II intercostal space region – 3.

In most cases, vascular anastomoses (16 cases) were at the III intercostal space level. The left internal thoracic artery diameter at this level was 3.0 (2.5-3.0) mm and the vein 3.0

(2.0-3.0) mm. At this level there were no problems in interarterial vascular anastomoses formation with middle colic artery 2.8 (2.5-3.0) mm because the vessels diameters were approximately equal (p=0.984). Intervenous anastomoses with middle colic vein 3.0 (2.9-3.0) mm were used in 8 cases (32%) due to differences in diameter (p=0.043).

When vascular anastomoses were formed at the level of IV intercostal space (6 cases) the left internal thoracic vessels diameters were lower than the middle colic vessels. Their arterial sizes were 2.5 (2.0-2.7) mm vs 2.8 (2.5-3.0) mm (p<0.015). We could form all interarterial anastomoses despite the difference in vessels diameters. At this level in 10 (40%) cases, the internal thoracic vein was in the form of two trunks of 1.5 (1.4- 1.6) mm in diameter. This was markedly lower than the diameter of the colic vascular pedicle vein 3.0 (2.9-3.0) mm (p<0.001). In these cases, the ratio of vein diameters in relation to the thickness of their walls showed inadvisability of intervenous vascularization. In the other 15 (60%) cases, vein diameters were also lower — 2.5 (2.0-3.0) vs 3.0 (2.9-3.0) mm (p<0.004).

In 3 observations, vascular anastomoses were done at the level of the II intercostal space. The internal thoracic artery diameter was 3.0 (2.7-3.0) mm (p=0.106) and vein 3.0 (3.0-3.1) mm (p=0.628). Both types of vascular anastomoses present no particular difficulties. Internal thoracic artery assessment to III intercostal space showed it was a single trunk gradual narrowing downwards. The internal thoracic artery began to divide at the level of the IV intercostal space in 40% of cases. The diameters of right and left internal thoracic vessels at the level I-VI i ntercostal spaces are given in Table 1.

Table 1 *Comparison of internal thoracic and middle colic vessels diameters*

Arteries			
Intercostal space	**Arteria thoracica internal diameter, mm**	**Arteria colica media diameter, mm**	**Wilcoxon criteria, p_z**
II	3.0 (2.7-3.0)		0.106
III	3.0 (2.5-3.0)	2.8 (2.5-3.0)	0.984
IV	2.5 (2.0-2.7)		0.015
Veins			
Intercostal space	**Vena thoracica internal diameter, mm**	**Vena colica media diameter, mm**	**Wilcoxon criteria, p_z**
II	3.0 (3.0-3.1)		0.628
III	3.0 (2.0-3.0)	3.0 (2.9-3.0)	0.043
IV (60%)	2.5 (2.0-3.0)		0.004
IV (40%)	1.4 (1.5;-1.6)		<0.001

It should be emphasized that the anatomical characteristics of the internal thoracic vessels were the same on both sides, as were the medians of their diameters at the level II-IV intercostal spaces (p>0.05), reflecting their spatial symmetry. The possibility of colic graft forming with sufficient length was proved during anatomical experiments. Graft was fully supplied by the vascular pedicle with the left colic artery only at 21 (84%) or in combination with accessory middle colic artery — 4 (16%). Also the diameter of the left colic artery was comparable with middle colic artery diameter — 2.6 (2.5; 2.8) mm vs 2.8 (2.5; 3.0) mm (p<0.111). In this regard, it is important to preserve anatomical blood supply at vascular augmentation to provide an anatomically integrated system of colonic blood supply to prevent ischemic complications.

These anatomical results became the prototype for using this surgery in patients with esophageal and gastroesophageal carcinomas requiring reconstruction (figure 5).

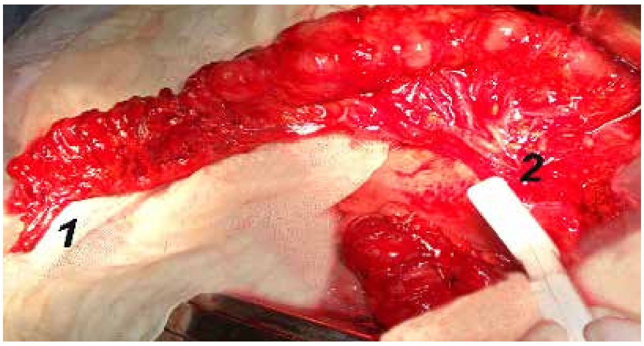

Figure 5 *Intraoperative dopplerography (1 — vascular pedicle of the colonic graft,*
2 — the main feeding vessel)

We also assessed the technical aspects of colic graft formation from the right colon flank with ileocecal corner preservation, and ligation of middle and right colic artery with graft length measurement. Mobilization of the right flank of the colon was performed with greater omentum preservation, as also the partial separation of the transverse colon with splenic ligament. The intersection of the transverse colon from the left flank was carried out with the ligation of small segmental vessels to about 4 cm. Options for vascular reinforcement have been performed on 9 male patients described above of average age 61, with an average body mass index of 23.2 (21.5-31.0) units.

Esophageal replacement by colon interposition for esophageal cancer was performed in 6 patients and for gastroesophageal cancer in 3. According to criterion T, these patients divided as follows: T1- 1 (11.1%), T2- 1 (11.1%), T3-5 (55.6%), T4-2 (22.2%) with (N+)–5 (55.6%) and without (N0)-4 (44.4%) lymph node metastasis. By cancer stage, 6 patients were stage II disease and 3 at stage III.

Esophageal replacement by colon interposition for esophageal cancer

Four patients underwent delayed reconstruction after transthoracic esophagectomy without reconstruction and 5 had repeated esophageal replacement after divisive procedure because of unsuccessful primary replacement with gastric tube (graft necrosis or intrapleural esophageal anastomotic leakage).The left internal thoracic artery was used as an additional blood supply, was anastomosed with middle colic artery in the 9 patients. Further intervenous anastomosis was performed in 3 patients (average operative time 6.5 h (300-420) min. Intraoperative blood loss was 300 (175-375) ml. The frequency of postoperative complications was 11.1% with no 30-day postoperative mortality. Post-operative complications included partial cervical esophageal anastomotic leak in 1 patient. In hospital stay was 23.2 (21.5-31.0) days, and 1-year survival 66.7±15.7% (median survival 16.0±0.2 (95% CI 15.5–16.5) months.

Discussion

Patients we operated upon had compromised stomach after its resection, gastrectomy, gastrostomy and graft insufficient length from the stomach or small intestine. The graft was formed from the ascending and transverse colon, and during operation we made full mobilization of the right colon flank and transverse colon with splenic ligament preservation. All patients had appendectomies. Using our method, we are able to save the functionally important ileocecal colon segment and form the graft from the right and transverse colon flanks in isoperistaltic position with ileocecal corner preservation. The main feeding vessel of the graft was the left colic artery and the Riolan arc. Colic graft was moved to the neck by a retrosternal route (figure 6). Thus its vascular mesentery was placed on the left and alongside of the stomach.

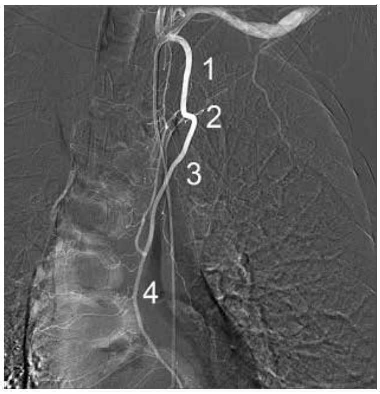

Figure 6 *Left mammarography (1 — internal thoracic artery, 2 — interarterial anastomotic zone, 3 — middle colic artery, 4 — marginal artery of the colonic graft)*

For vascular anastomosis, recipient zone by the cartilaginous part of an appropriate rib resection at the level of vascular pedicle with colic vessels was carried out. This gave free space in the left mediastinal space needed for the left internal thoracic vessels mobilization; it helps to lead the mesenteric vascular pedicle of the graft from a retrosternal tunnel without tension. From our work we have established the technical possibility of vascular interarterial anastomoses and shown technical difficulties creating vascular intervenous anastomoses in clinical practice (figure 7).

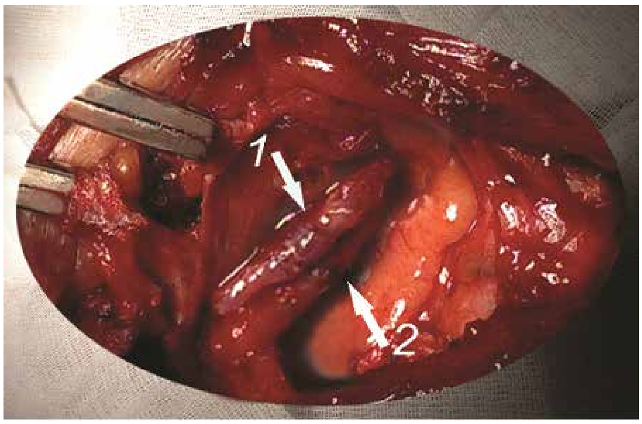

Figure 7 *Vascular anastomoses in the left mediastinal space (1 — intervenous anastomosis, 2 — interarterial anastomosis)*

Vascular anastomosis location in the left mediastinal space creates an anatomical barrier between vascular anastomoses and esophageal anastomosis, with its high potential risk of septic complications on the neck area. Level selection for vascular anastomosis depends on the colic vascular anatomy. It usually extends from rib II to IV. Based on our data, the technical possibility of vascular interarterial anastomoses formation is confirmed and also illustrates some of the technical difficulties in clinical practice. This study serves as a prototype for surgery on patients with esophageal diseases, notable cancer, requiring esophageal replacement. The proposed variant of vascular augmentation provides an adequate blood supply to the colonic graft and reduces ischemic complications postoperatively, confirming its value in this particular type of reconstructive surgery. The study of different methods of revascularization of intestinal autografts will help to reduce morbidity and mortality in these patients.

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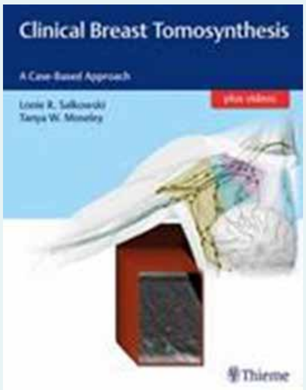
BOOK REVIEW

Clinical Breast Tomosynthesis - a Case-Based Approach

Lonie Salkowski and Tanya Moseley. Published by: Thieme Publishers New York/Stuttgart. 2017, 272 pp, 420 illustrations, ISBN: 9781626231474



Tumerous articles have been published over the last decade demonstrating the improved diagnostic accuracy of digital breast tomosynthesis (DBT) compared to convention 2D digital mammography (2DDM) and DBT is now being implemented in diagnostic breast imaging practices across the United Kingdom. There remains an ongoing debate regarding the use of DBT for routine breast cancer screening. Clinical Breast Tomosynthesis is a case based teaching atlas which reflects the extensive experience of breast imaging of Professors Lonie Salkowski and Tanya Moseley in their renowned breast diagnostic centres in North America. This comprehensive textbook is therefore is a welcome addition to the currently available mammography texts which are illustrated primarily with 2DDM images.

The book is divided into eight parts. The first part contains a succinct account of the physics of DBT and a summary of the BIRADS Lexicon. The remaining sections of the book consist of groups of cases arranged according to the role played by DBT, e.g. further assessment required for an abnormality found on DBT screening, or DBT assessment following screening with 2D mammography. For each case there is a summary of the mammographic findings, a discussion of the differential diagnosis, a list of essential facts and relevant learning points and a short reference list. The mammograms are displayed with and without annotation, and further images including relevant tomosynthesis slices, spot compression views, ultrasound and MRI are included. The quality of the images is generally very good but in some cases very subtle soft tissue abnormalities or fine microcalcification are difficult to visualise and the quality could have been improved by further cropping and display of an enlarged image. The teaching value of this book is greatly enhanced by the inclusion of 238 videos of tomosynthesis examinations which are easily accessed online - for each case the tomosynthesis cine-loop can be viewed alongside the printed images and accompanying text.

Readers from the UK will note some differences in clinical practice compared to North America and may question the use of mammography in women in their thirties and the practice of six months follow up for probably benign lesions. This however should not detract from the quality of this excellent book which has been well written and comprehensively illustrated. It will be of particular value to breast diagnostic departments which are currently integrating DBT into their clinical practice.

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