

# Clinical outcomes and radiological assessment of vascular anatomy in patients who underwent D3 left hemicolectomy

## Resultados clínicos y evaluación radiológica de la anatomía vascular en pacientes sometidos a hemicolectomía izquierda D3

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### Abstract

**Background.** Adequate blood supply is one of the key factors for colorectal anastomosis healing. Various variants of vascular anatomy often come as a surprise to surgeons during operations. **Objectives.** The aims of this study were to carry out a comparative analysis of three-dimensional-computed tomography (3D-CT) angiography data with intraoperative data and a detailed analysis of variants of the anatomy of splenic flexure. **Material and methods.** In this study, we included 103 patients (56 males and 47 females; mean age  $64.2 \pm 11.6$ ) with the left-sided colon and rectal cancer who underwent preoperative 3D-CT angiography at Ternopil University Hospital between 2016 and 2022. **Results.** According to the recently proposed classification, there are four types of blood supply to the splenic flexure of the colon: Our analysis showed that type 1 was found in 83 (80.6%) patients, type 2 in 9 (8.7%), type 3 in 10 (9.7%), and type 4 in 1 (1%). All patients underwent local left radical hemicolectomy with resection of complete mesocolic excision (CME), central vascular ligation (CVL) and resection (R0). Seven cases were operated laparoscopically; and the median quantity of removal lymph nodes was  $21.54 \pm 7.32$ . Positive lymph nodes were revealed in 24.3% cases. AL was diagnosed in one patient. **Conclusions.** Careful pre-operative analysis of vascular anatomy on 3D-CT angiography will assess the vascularization of the splenic flexure of the colon, reduce intraoperative time to identify structures, and develop a personalized strategy for surgery which potentially can reduce the risk of anastomotic leakage.

**Keywords:** Three-dimensional-computed tomography angiography. Left colic artery. D3 lymph node dissection. Colorectal cancer.

### Resumen

**Antecedentes.** El suministro de sangre adecuado es uno de los factores clave para la curación de la anastomosis colorrectal. Varias variantes de la anatomía vascular a menudo sorprenden a los cirujanos durante las operaciones. **Objetivo.** Realizar un análisis comparativo de los datos de la angiografía tridimensional por tomografía computarizada (3D-TC) con los datos intraoperatorios y un análisis detallado de las variantes de la anatomía del ángulo esplénico. **Método.** Se incluyeron en el estudio 103 pacientes con cáncer de colon y recto del lado izquierdo que se sometieron a una angiografía 3D-TC preoperatoria en el Hospital Universitario de Ternopil. **Resultados.** De acuerdo con la clasificación propuesta recientemente, existen cuatro tipos de irrigación del ángulo esplénico del colon. Nuestro análisis mostró que el tipo 1 se encontró en 83 (80.6%)

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pacientes, el tipo 2 en 9 (8.7%), el tipo 3 en 10 (9.7%) y el tipo 4 en 1 (1%). Todos los pacientes fueron sometidos a hemicolectomía radical izquierda local con resección de escisión mesocólica completa (CME), ligadura vascular central (CVL) y resección (R0). Siete pacientes fueron operados por vía laparoscópica. La mediana de ganglios extirpados fue de  $21.54 \pm 7.32$ . Se revelaron ganglios linfáticos positivos en el 24.3% de los casos. Se diagnosticó fuga anastomótica en un paciente. **Conclusiones.** El análisis preoperatorio cuidadoso de la anatomía vascular en la angiografía 3D-TC evaluará la vascularización del ángulo esplénico del colon, reducirá el tiempo intraoperatorio para identificar estructuras y desarrollará una estrategia personalizada para la cirugía.

**Palabras clave:** Angiografía 3D-TT. Arteria cólica izquierda. Linfadenectomía D3. Cáncer colorrectal.

## Introduction

Anastomotic leakage (AL) is an eternal problem in surgery. Pre-operative identification of AL risk factors is a key point. One of the most significant etiological factors of its various disorders with blood supply<sup>1</sup>. The colon is protected from ischemia by well-developed collaterals, including the Drummond marginal artery and arcade anastomoses between the basins of the superior (SMA) and inferior mesenteric arteries (IMA). It is well known that vascular anatomy is quite variable and the colon has certain vulnerabilities, some authors call them ischemic zones<sup>2,3</sup>. Of particular interest is the Griffith Point, which is located in the mesentery of the splenic angle of the colon and is one of the so-called “blind”, ischemic or least blood-supplied areas of the colon, as it is located on the border of the ascending branch of the left colon and Drummond’s marginal artery. Approximately 5% of patients do not have this anastomosis and small capillary network may be absent for 1.2-2.8 cm<sup>3</sup> of mesentery area<sup>4</sup>. Moreover, the splenic flexure of the colon is the boundary between two different embryological rudiments: middle (forms the distal duodenum, small intestine, cecum, ascending, and proximal two-thirds of the transverse colon) and posterior (forms the distal third of transverse colon, descending, sigmoid, and rectum) intestines. Different embryological roots also contribute to the different biology of the tumor process proximal and distal to the splenic angle<sup>5</sup>.

It should be noted that the splenic flexure is also considered one of the most difficult and complex anatomical parts of the colon for mobilization during laparoscopic surgery for colorectal cancer (CRC)<sup>6</sup>. The difficulty of performing such operations is added by various anatomical variants of the structure of the branches of the SMA and IMA. According to the literature, the frequency of AL when performing left hemicolectomy is 5-10%<sup>7</sup>.

Widely implemented in clinical practice, three-dimensional-computed tomography (3D-CT) angiography allows the analysis of vascular anatomy in the pre-operative stage and has a clear 3D reconstruction during left hemicolectomy<sup>8,9</sup>. It is important to adhere strictly to the scanning protocol, as well as to take into account the individual comorbid aspects of each patient, which may affect the quality of the data obtained.

The aim of the given article is to analyze the clinical and radiological aspects of patients with cancer of distal third of transverse and left-sided colon, which usually need to be discussed before a surgery by a multidisciplinary team as well as to carry out a comparative analysis of 3D-CT angiography data with intraoperative data and a detailed analysis of variants of the anatomy of splenic flexure, to conduct a retrospective analysis of the results of surgical treatment in patients who underwent left hemicolectomy.

## Methods

### *Description of patients*

In this study, we included 103 patients (56 males and 47 females; mean age  $64.2 \pm 11.6$ ) with the left-sided colon and rectal cancer who underwent pre-operative 3D-CT angiography at Ternopil University Hospital between 2016 and 2022. The exclusion criteria were stage IV process and locally advanced forms of cancer. Furthermore, from the retrospective analysis, we excluded cases where the examination was performed with non-compliance with the scanning protocol or for one reason or another it was performed without contrast. The informed consents were obtained from all patients, and this study was passed by the ethics commission of Ternopil National Medical University.

### *Scan protocol*

3D-CT angiography was performed using a Philips Brilliance 64 CT machine with IV contrast (100 mL of

iodinated contrast agent [370 mg/mL]). Contrast was injected into the ulnar vein at a rate of 4.5 mL/s. The bolus tracking method was used for scanning. Arterial phase scanning automatically began when the contrast in the abdominal aorta at the level of the abdominal trunk reached 180 HU. The 64-slice multidetector CT scanner can generate 0.75 mm slices that can be reconstructed into a 0.5 mm image. Therefore, to obtain high-quality CT angiography for preoperative analysis, a scanning protocol should be maintained: sublingual nitrate intake, high contrast rate (4-5 mL/s), early arterial phase (20-30'), stress reduction (80-100 kV), and doubling the mAs. Image processing was performed using 3D volume imaging technique, VRT, and MIP. All patients underwent standard bowel preparation for CT (dietary + laxative).

### Statistical analysis

Quantitative variables were calculated with the use of the median. All calculations were performed using the Statistica 64 software.

## Results

### Radiological results

According to the recently proposed classification, there are four types of blood supply to the splenic flexure of the colon: Type 1 – the left branch of the middle colic artery (LMCA) branches from the common trunk of middle colic artery (MCA) + left colic artery (LCA); type 2 – LMCA branches independently of the right branch of the MCA directly from the SMA + LCA; type 3 – additional middle colic artery (AMCA) + LCA; and type 4 – splenic flexure of the colon is supplied exclusively by LCA<sup>8</sup>. Our analysis showed that type 1 was found in 83 (80.6%) patients, type 2 in 9 (8.7%) patients, type 3 in 10 (9.7%) patients, and type 4 in 1 (1%) patient.

In the arterial structure of the splenic flexure of the colon, there are several arcades: the aforementioned marginal artery of Drummond, as well as the arc of Riolan and the artery of Moskovich<sup>1,6</sup>.

Marginal artery of Drummond is a collateral pathway that connects the SMA and IMA systems closest to the colon wall<sup>1</sup>. In our study, we found the presence of this artery in all 103 (100%) patients (Figs. 1-3).

Riolan's arch is an "intermediate" anastomosis between the branches of the SMA and IMA in the mesentery of the colon<sup>2,4</sup>. In our study, we found the presence of this structure in 47 (45.6%) patients (Figs. 1-3).

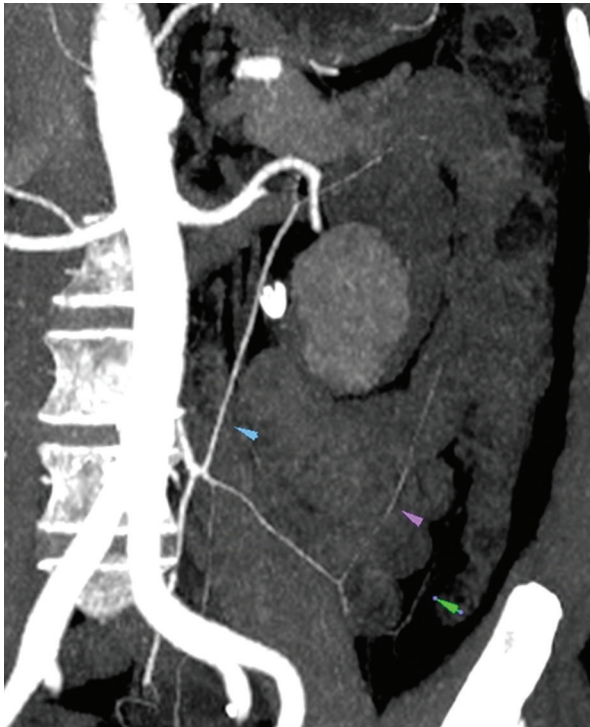


**Figure 1.** Three dimensional-computed tomography angiography: Riolan's arc (transverse arrows) and Drummond's marginal artery (longitudinal arrows).



**Figure 2.** Three-dimensional-computed tomography angiography: Moskovich's artery marked by arrows (MeA). IMA: inferior mesenteric artery; MCA: middle colic artery.

The Moshkovich's artery, also known as the tortuous mesenteric artery, is a lesser-known collateral route and is another link between the SMA and IMA. The



**Figure 3.** Two dimensional-computed tomography angiography: left to right vascular arcades of Moshkovich, Riolan and Drummond.

Moshkovich's artery runs along the base of the mesentery of the colon and is the connecting link between the proximal segment of the MCA and the ascending branch of the LCA<sup>2,6</sup>. In our study, we found the presence of this artery in only 1 (1%) patient (Fig. 2 and 3).

Analysis of the course of IMV showed that most often IMV flowed into the splenic vein (SV), there were 72 (69.9%) of such cases, IMV fell into superior mesenteric vein (SMV) in 27 (26.2%) patients, and IMV, SV, and SMV created a common confluence of the portal vein in 4 (3.9%) patients. We do not observe any venous injuries during mobilisation.

### Clinical results

All patients underwent local radical left hemicolectomy with complete mesocolic excision (CME), central vascular ligation (CVL), and R0 resection; one case was operated laparoscopically; the median quantity of removal lymph nodes was  $21.54 \pm 7.32$  (range 12-45). Positive lymph nodes were revealed in 24.3% cases. The incidence of metastatic lymph nodes in D1 zone was 25%, D2 zone – 6.2%, and the zone D3 – 3.1%. Mean operative time was 82 min (range 63-130 min). Median intraoperative blood loss

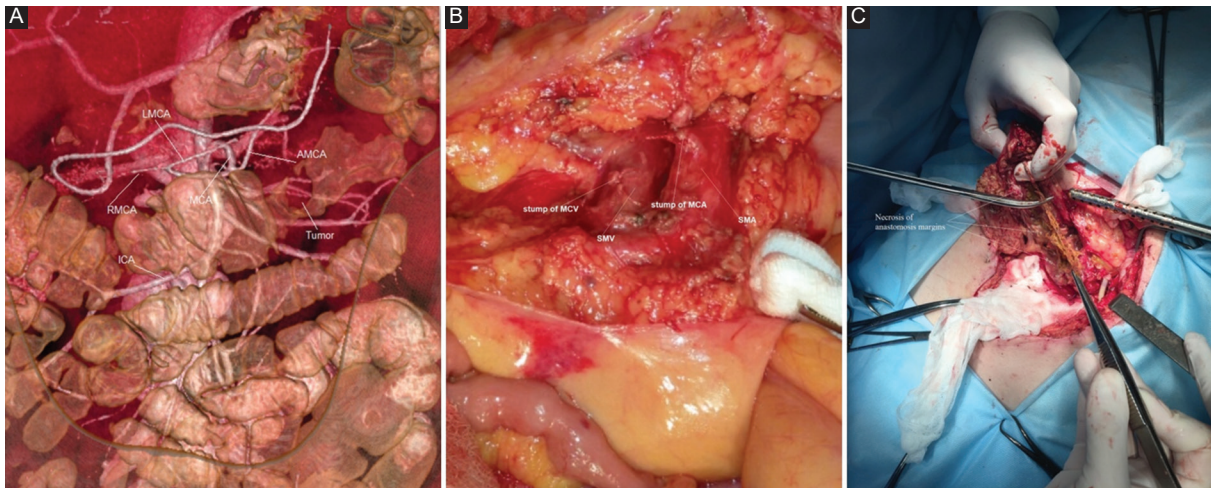
was 65 mL (range, 32-280 mL); no patients required intraoperative blood transfusion. Post-operative complications were developed in seven patients. AL was diagnosed in one patient on the 8<sup>th</sup> post-operative day for whom relaparotomy, lavage and end stoma were performed (Fig. 4). Unfortunately, on the 1<sup>st</sup> day after patient discharge from the hospital, he died from massive thromboembolic complication despite maintaining prophylaxis therapy. Retrospective analysis of 3D-CT angiography showed the presence of third type of blood supply to the splenic flexure of the colon (AMCA + LCA) (Fig. 4). Due to oncological radicalism and the requirements of D3 lymphadenectomy, MCA was ligated in the base of SMA (tumor was located were closely to both branches of MCA), which caused irreversible ischemic changes in the area of anastomosis on the 8<sup>th</sup> post-operative day.

One patient suffered from paralytic ileus in an early post-operative period. Median staying in hospital after operation was 8.4 days.

### Discussion

The most critical post-operative complication in patients with CRC is AL. The key factors that affect AL are the condition of blood supply to the edges of the anastomosis and its tension<sup>1</sup>. According to the literature, the incidence of AL after the left hemicolectomy is 5-10%. In our study, we have found out that the AL was in one case.

The ischemic zone of the splenic flexure of the colon is a serious risk factor for AL, because the disruption of blood supply to both ends of the anastomosis leads to the development of this complication. Some authors believe that the three vascular arcades of Drummond, Riolan, and Moshkovich should be excluded from use in the scientific literature, and instead introduce the concepts: marginal artery (most peripheral arcade), "V-shaped (intermediate) arcade" end of the ascending branch of LCA and LMCA or AMCA and "rare" intermesenteric trunk, which is located more centrally in the mesentery of the colon<sup>2</sup>. Nevertheless, the presence, detection, and evaluation of these vascular arcades at the preoperative stage of 3D-CT angiography analysis are an important element of surgery planning. For most surgeons when performing open or laparoscopic left hemicolectomy, the presence of a proximal arcade between the systems of SMA and IMA (Moshkovich's artery) is an unexpected finding and a debatable question in the feasibility of its ligation<sup>6</sup>.



**Figure 4.** Clinical case of anastomotic leakage (AL). **A:** intraoperative photo after D3 lymphadenectomy (SMA – superior mesenteric artery, SMV – superior mesenteric vein, stump of MCA and MCV); **B:** retrospective 3D reconstruction; **C:** relaparotomy, AL (necrosis of anastomosis margins).

CME, CVL with D3 lymph node dissection, is the widely accepted surgical concept in colon cancer. However, the incidence of metastasis in the apical group of lymph nodes (D3 zone) in our study observed only in 3.1% cases, according to the literature ranges from 3% to 11%<sup>3,4</sup>. By the way, the left-sided colon cancer has less aggressive tumor biology so it is needed further investigations and standardization about the volume of lymphadenectomy, especially D3 zone of middle and distal thirds of transverse colon<sup>9</sup>.

In arterial supply of splenic flexure, quite rarely present AMCA which passes caudally to the lower margin of the pancreas to the distal transverse colon<sup>10-12</sup>. In our study, we found that AMCA was present in 10 (9.7%) cases and originated from MCA. It is a sophisticated question about the arterial structure of splenic flexure because we have not only the aim to make resection, but, firstly, we should perform the correct and radical oncological procedure. It is not a debatable question to preserve the feeding tumor artery in the case of cancer of splenic flexure. In the literature, there are some studies that describe originating AMCA from IMA or even from celiac arteries<sup>12</sup>. Another interesting and not completely standardized question is who and how classifies certain structures, specifically in the case when AMCA originated from IMA or maybe it is Moshkovich artery. By the way, for all colorectal surgeons, the presence of AMCA or Moshkovich artery is always a surprise during operation and it is another one of the arguments for careful assessment of pre-operative 3D CT angiography.

Along with the arterial anatomy, it is also important to have a clear understanding of the course of the venous branches (IMV, SV, and MCV) tangential to the splenic angle of the colon to avoid their damage<sup>10,11</sup>.

Contrast-enhanced CT is the gold standard for diagnosing and staging patients with colon cancer and distant metastases<sup>9,12</sup>. 3D-CT angiography is a noninvasive modality which can be useful for preoperatively evaluating the vascular anatomy of the colon. 3D reconstruction can demonstrate different rare abnormalities. The goal of the 3D-CT angiography is not just about the acquisition of a “pretty picture” but could have additional diagnostic value especially in rare «casuistic» abnormalities. When staging a colorectal cancer, it is essential to achieve an early arterial phase of upper and lower abdomen in addition to venous phase. Early arterial phase 20-30 s post injection or immediately after bolus tracking is the phase of the best visualization and further 3D reconstruction of the arteries<sup>13</sup>. However, 3D CT angiography has a number of diagnostic limitations. First, the pre-operative CT protocol for patients with colon cancer usually does not involve performing an early arterial phase, which makes it difficult to perform adequate 3D reconstruction. Second, the caliber of the SMA and IMA branches is usually small and cannot always be well visualized on 3D-CT angiography. In the preoperative assessment of such vascular structures of the splenic angle of the colon as: Drumond’s marginal artery, Riolan’s arch and to a lesser extent Moshkovich’s artery, this creates additional visualization difficulties. This fact is a significant limitation in the qualitative assessment of pre-operative

vascular anatomy. In case of poor visualization of the above structures on 3D-CT angiography, the analysis should be performed in the usual 2D mode<sup>3,7,8</sup>.

Actually, our study has some limitations. This study is partly retrospective (observation period from 2016 to 2018) and partly prospective (observation period from 2019 to 2022), so we can not fully conduct an effective analysis between anatomical variations of vascular anatomy with post-operative complications in a group of cases that were retrospectively analyzed.

## Conclusions

Careful pre-operative analysis of vascular anatomy on 3D-CT angiography will assess the vascularization of the splenic flexure of the colon, reduce intraoperative time to identify structures, and develop a personalized strategy for surgery which potentially can reduce the risk of AL. Identification and taking for consideration of rare types of vascular supply of splenic flexure is a key point in avoiding surgical complications. New studies and further standardization for transverse colon cancer are needed to provide.

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## Conflicts of interest

The authors declare no conflicts of interest.

## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that no experiments were performed on humans or animals for this study.

**Confidentiality of data.** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Right to privacy and informed consent.** The authors have obtained approval from the Ethics Committee for analysis and publication of routinely acquired clinical data and informed consent was not required for this retrospective observational study.

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