https://doi.org/10.33878/2073-7556-2024-23-3-87-99

Computed tomography in quality control of surgery for right colon cancer

Anna A. Kholeva[1], Tatev A. Agababian[1], Aleksey A. Nevolskikh[1], Violetta A. Avdeenko[1], Sergey A. Ivanov[1,3], Andrey D. Kaprin[2,3]

[1]A.Tsyb Medical Radiological Research Centre branch of the Medical Radiological Research Centre (Marshal Zhukov st., 10, Kaluga region, Obninsk, 249031, Russia)
[2]National Medical Research Radiological Centre (Koroleva st., 4, Kaluga region, Obninsk, 249036, Russia)
[3]Peoples' Friendship University of Russia, RUDN University (Miklukho-Maklaya st., 6, Moscow, 117198, Russia)

ABSTRACT *AIM: to assess the length of the stump of the feeding arteries of the right colon, their anatomical location relative to the superior mesenteric vein (SMV), the level of ligation of the main arteries after right hemicolectomy with D2- and D3-lymphadenectomy.*

PATIENTS AND METHODS: the retrospective study included 82 patients with a histologically confirmed right colon cancer aged 44-88 (mean 68) years. All patients underwent right hemicolectomy. In 40 cases, D2 lymph node dissection was performed, in 42 cases — in D3. Preoperatively, all patients were assessed for the location of the ileocolic and right colon arteries relative to the SMV and the expected length of their stumps was measured by CT. Postoperatively, the actual length of the stumps was assessed. RESULTS: CT images of the ileocolic artery stump were obtained in 76 (92.6%) of 82 patients. In 6 patients, a metal clips were installed along the contour of the superior mesenteric artery; in such cases, a clear CT image of the stump of the ileocolic artery was not obtained, and the length of the stump was assessed as 0 mm. The stump of the right colic artery was determined in all patients in whom the artery was identified preoperatively. The ventral location of the ileocolic artery relative to the SMV according to CT data was identified in 38 (46.3%) of 82 patients, the dorsal location — in 44 (53.7%) of 82 patients. With the ventral location of the ileocolic artery relative to the SMV in patients with D2, the length of the artery was 14.3 (8-25.6) mm, with D3 — 7.6 (3.3–11.1) mm ($p = 0.005$). With the dorsal location of the ileocolic artery relative to the SMV in patients with D2, the length of the artery was 8.8 (4.9–16.2) mm, with D3 — 3.9 (1–6.9) mm ($p = 0.004$).

CONCLUSION: the actual length of the stump of the feeding artery can become an indicator of the level of ligation of the main arteries and, indirectly, the extent of lymphadenectomy after right hemicolectomy. Further studies with a larger number of cases are needed to confirm the hypothesis for measuring the length of the stump of the feeding arteries as a marker of the extent of the procedure performed.

KEYWORDS: *right-sided colon cancer, right hemicolectomy, computed tomography, ileocolic arterial stump*

CONFLICT OF INTEREST: *the authors declare no conflict of interest*

FOR CITATION: Kholeva A.A., Agababian T.A., Nevolskikh A.A., Avdeenko V.A., Ivanov S.A., Kaprin A.D. Computed tomography in quality control of surgery for right colon cancer. *Koloproktologia*. 2024;23(3):87–99. (in Russ.). https://doi.org/10.33878/2073-7556-2024-23-3-87-99

ADDRESS FOR CORRESPONDENCE: *Kholeva A.A., A.Tsyb Medical Radiological Research Centre branch of the Medical Radiological Research Centre, Marshal Zhukov st., 10, Kaluga region, Obninsk, 249031, Russia; e-mail: an.net-07@mail.ru*

Received — 05.06.2024 *Revised — 28.06.2024* *Accepted for publication — 01.08.2024*

INTRODUCTION

Every year, large intestine cancer occupies one of the leading places in the structure of cancer morbidity and mortality. In 2020, according to the Globocan IARC, more than 1.9 million cases of colorectal cancer (CRC) were detected worldwide, which corresponds to the third place after lung cancer and breast cancer [1]. According to European studies, right colon cancer (RCC) accounts for 30–38% of CRC cases [2,3]. It is noted that RCC is associated with a number of negative prognostic factors, such as old age, the stage of the process and the mucinous structure of the tumor, and survival in patients with tumors of the right colon is lower compared with patients with cancer of the left colon [4,5]. The only radical treatment for RCC is surgical.

According to Russian clinical guidelines [6], when the tumor is sited in the caecum, ascending colon, hepatic flexure of the colon and the proximal third of the transverse colon, it is recommended to perform right hemicolectomy (RHC) or extended RHC. At the same time, surgery is carried out according to the principles of total mesocolic excision (TME), in the classical version proposed by Hohenberger for colon cancer in 2009 [7]. The modern TME technique in the European understanding is based on a precision technique of mobilizing the large intestine mainly by acute means within the existing embryonic layers in a single case with its own fascia covering the colon, lymph nodes and potential tumor metastases with high ligation of the main vessels [8]. The TME has been included in the clinical guidelines for colon cancer, both in the country and in Europe[6,9]. However, there are conflicting opinions regarding the volume of lymph node groups to be removed and differences in understanding high vascular ligation in RCC.

The number of removed lymph nodes is an important prognostic factor in RCC [10,11]. The lymph nodes of the colon are located along the arteries. According to the Japanese classification, there are three groups of regional lymph nodes of the colon: 1. Paracolic lymph nodes along marginal vessels (first level); 2. Mesocolic or intermediate lymph nodes along main vessels (second level); 3. Apical lymph nodes in the area of ramification of vessels from the main artery (third level) [12]. The D2 lymph node dissection includes the removal of paracolic and mesocolic lymph nodes, the volume of D3 lymph node dissection in addition to the volume of D2 lymph node dissection includes the removal of apical lymph nodes. The standard volume of the procedure, according to both Russian and European guidelines, includes D2 lymph node dissection [8,13], whereas according to Japanese clinical guidelines, it is necessary to perform D3 lymphnode dissection in all cases, except for stage I [14].

Another concept on the volume of surgery for colon cancer is high vascular ligation. There are various approaches to performing high vascular ligation in RCC. Thus, in the consensus of 2012, the ligation at a distance of 1 cm from the main artery is considered safe [13]. The consensus on the RSCC of 2022 states the need for visualization of SMV when performing high ligation of the feeding arteries [8]. The Russian Guidelines for RH indicate the need for ligation at the base of the ileocolic artery, the right colic artery, as well as the middle colon artery at the base or the right branch of the middle colon artery [6]. Presumably, high vascular ligation is accompanied by an increase in the number of lymph nodes to be removed [7,15].However, it should be noted that high vascular ligation and D3-lymph dissection imply the removal of various amounts of fatty tissue and, accordingly, a different number of lymph nodes [16].

The method of assessing the quality of the performed surgery is morphological data, such as macroscopic assessment of the quality of TME, including assessment of the plane and edges of resection, the number of removed and affected lymph nodes, which are prognostic markers of locoregional recurrences and disease progression [10,11]. However, to date, there are no standardized methods for postoperative assessment and quality control of performing high ligation of the main arteries. West (2010) proposed a pathomorphological method for evaluating resected samples by measuring the distance between the tumor and the ligation point of the feeding arteries and between the intestinal wall and the ligation point of the feeding arteries [15,17]. However, this does not directly reflect the length of the residual stump of the ligated artery [18].

Previous studies have shown that CT imaging of the stump of the vessel is possible in months and even years after surgery [18,19]. Thus, lifetime measurement of the length of the remaining stump of the vessel is possible and can serve as a valuable indicator of the quality of the volume of lymph dissection.

THE AIM OF THE STUDY

Determination of CT capabilities in assessing the stump length of the ligated arteries of the right colon, taking into account their anatomical site relative to the superior mesenteric vein (SMV) to determine the level of ligation of the main arteries during right hemicolectomy (RH) with D2 and D3 lymph dissection.

PATIENTS AND METHODS

The retrospective study included 82 patients (45 women and 37 men) with a histologically confirmed diagnosis of RCC aged 44 to 88 years (average age 68 years). All patients underwent surgery (RH) in 2018–2024. At the same time, 68 patients underwent laparoscopic procedure, 11 patients underwent open surgery. In three cases, conversion was required. In 40 cases, surgery was performed iasD2 lymph node dissection and in 42 cases — D3.

At the preoperative stage, CT was performed for staging, at the postoperative stage — as part of checkup.

CT was carried out on Optima CT 660 CT scanners (General Electric, USA) and SOMATOM go. TOP (Siemens, Germany). In 4 patients, preoperative CT data were provided from other institutions.

During the research on the Optima CT 660 computed tomography (64-slice, General Electric, USA), the following scanning parameters were set: tube voltage 120 kV, power current 100–500 mA, tube rotation time 0.6 seconds, pitch 1.375, slice thickness 5 mm. Scanning was performed in native, arterial (30 seconds) and venous (60–70 seconds). Image reconstruction in contrast phases was performed with a slice thickness of 1.25 mm. The processing of the received images was performed on the Advantage Workstation Volume Share 4.6.

During the test on the SOMATOM go. TOP tomograph (64/128-slice, Siemens, Germany), the following scanning parameters were set: collimation 64 × 0.6, tube voltage 120 kV, tube rotation time 0.6 seconds, pitch 1.35. Image reconstruction was carried out using the iterative SAFIRE 3 algorithm. Scanning was performed in the native, arterial (starting scanning using the Bolus Tracking technique) and venous phases. The reconstruction of images into contrasting phases was carried out with a slice thickness of 1.0 mm. The processing of the received data was carried out on the Syngo.via workstation.

The contrast agent was injected bolus using automatic injectors. Nonionic iodine-containing contrast agents with an iodine concentration of 350–370 mg/ml in a volume of 1.5–2 ml/kg were used as contrast agents. The imaging included oral administration of an X-ray contrast agent 12, 6 and 3 hours before the study. The analysis of the obtained images in order to measure the expected and actual length of the stump of the ileocolic and right colon arteries was performed using multiplanar reconstructions in the axial, coronary, sagittal or oblique planes and MIP reconstructions. The expected length of the stump of the ileocolic and right colon arteries at the preoperative stage was estimated depending on the location of the arteries relative to the SMV. With a ventral arrangement of the ileocolic artery relative to the SMV, the expected length of the artery stump was measured as the distance from the mouth of the artery to the medial contour of the vein, with a dorsal arrangement — as the distance from the mouth of the artery to the lateral contour of the vein.

Also, with the ventral location of the right colic artery relative to the SMV, the expected length of the artery stump was measured as the distance from the ostium of the artery to the medial contour of the vein, with the dorsal location — as the distance from the ostium of the artery to the lateral contour of the vein (Fig. 1).

The actual length of the artery stump was measured on postoperative CT data. In the case of artery ligation using metal clips, the measurement was carried out from the ostium of the artery to the metal clip. In the absence of a metal clip, the stump of the artery was measured along the entire visible length. In cases of complexities in

identifying the artery stump, comparison with preoperative images was carried out. Statistical processing of the obtained data was performed using the IBM SPSS Statistics 27 package (Armonk, NY: IBM Corp.). The Shapiro-Wilk criterion was used to check whether the observed sample belonged to a normal general aggregate. The Wilcoxon T-test was used to check the differences between the expected and actual stump lengths of the ileocolic and right colon arteries, to assess the differences between the actual stump length of the ileocolic artery with a different location of the artery relative to the SMV and to assess the differences between the actual stump length of the ileocolic artery during laparoscopic and open surgeries — the U-test Mann–Whitney test with the determination of the value of the probability integral (*p*-value). Spearman's rank correlation test was used to assess the relationship between the actual length of the ileocolic artery stump, the volume of blood

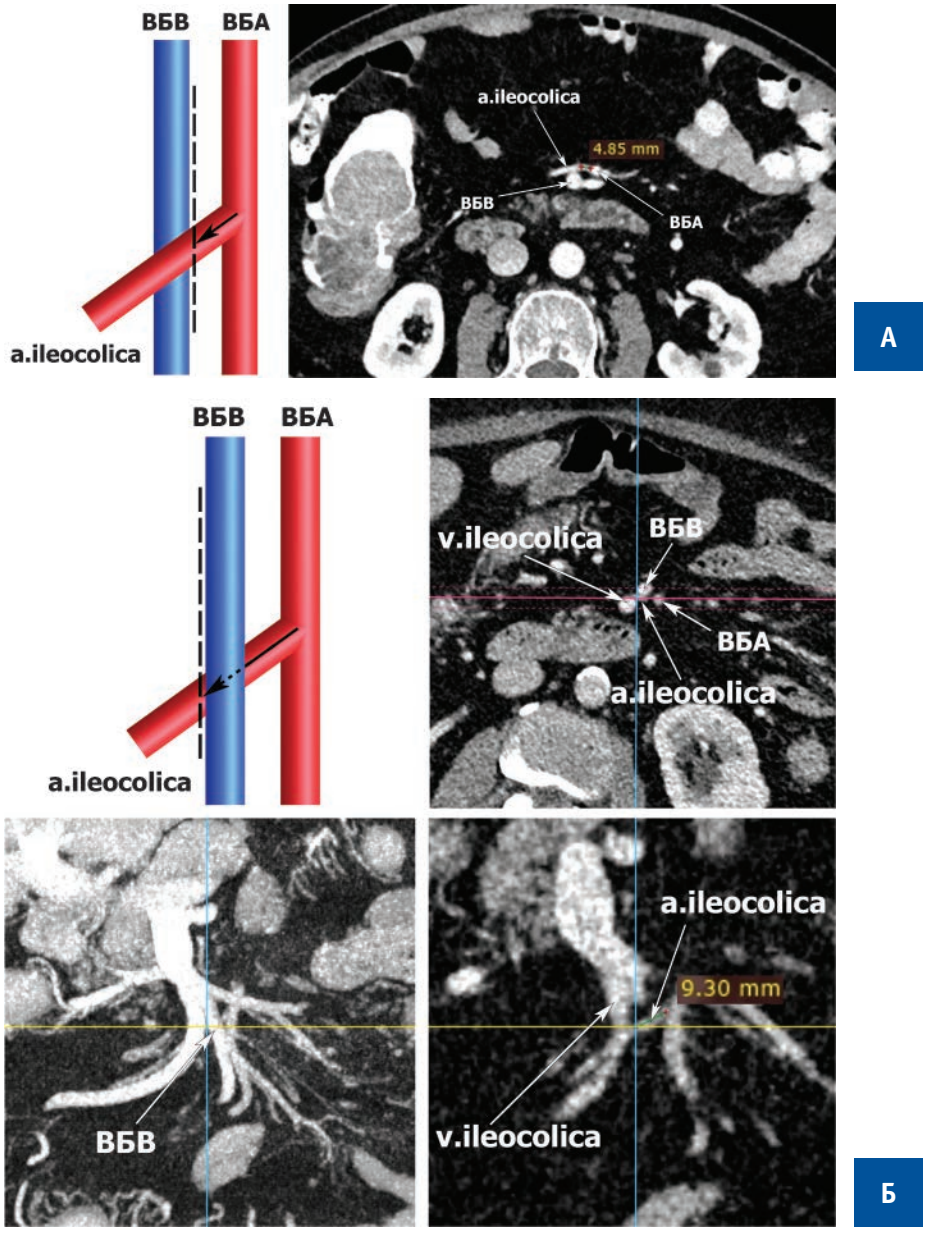

Figure 1. *A) Measurement of the expected stump length of the of the ileocolic artery according to CT data with the ventral location of the artery relative to the SMV (axial plane); Б) Measurement of the expected stump length of the of the ileocolic artery according to CT data with the dorsal location of the artery relative to the SMV (axial plane, MIP, coronal plane)*

loss during surgery, the operation time and the hospital-stay (days), as well as for actual length of the ileocolic artery stump and the number of lymph nodes assessed. To assess the differences between the length of the ileocolic artery stump and the presence of complications, the χ^2 test was used, followed by the determination of the value of the probability integral (p-value). The differences were considered significant at $p < 0.05$.

RESULTS

In the study group, the distribution of tumor site was as follows: caecum — 29 patients, ascending colon — 31 patients, hepatic flexure — 12 patients, transverse colon — 10 patients.

According to the CT data, the ventral location of the ileocolic artery relative to SMV was revealed in 38 (46.3%) of 82 patients, the dorsal location — in 44 (53.7%, 44/82). The results obtained were fully confirmed by the intraoperative data.

The assessment of the actual length of the ileocolic artery stump was carried out according to the data of the first postoperative CT (5.6 months after surgery). In 11 (13.6%, 11/82) patients, the analysis was performed according to the CT scans performed in between the 2nd and 10thdays after surgery in order to diagnose postoperative complications. In 47 (57.3%, 47/82) patients, repeated CT were presented in the Center's database, while in 9 people the time of repeated CT exceeded 3 years. The time of post-op CT, taking into account repeated studies, was 1 year and 2 months.

Metal clips in the stump of the ileocolic artery were visualized in 66 (80.5%, 66/82) patients. As a rule, the stump of the ileocolic artery in the venous phase was visualized as a soft-tissue strand with uneven contours corresponding to the course of the artery on preoperative CT (Fig. 2). In 6 patients, a metal clip was installed along the contour of the SMA, in such cases, a clear CT image of the stump of the ileocolic artery was not obtained, and the length of the stump was regarded as 0 mm. Thus, the image of the ileocolic artery stump was obtained by CT in 76 (92.6%) of 82 patients. In all patients with an image of the ileocolic artery stump according to CT data, when evaluating the data of repeated postoperative examination, including those performed more than 3 years after surgery, an image of the artery stump was obtained, while in a number of patients there was a decrease in its width and an increase in the clarity of the external contours (Fig. 3).

The distribution of the data obtained for the expected and actual lengths of the ileocolic artery stump with ventral and dorsal artery locations is shown in Figure 4. The median of the expected length of the ileocolic artery stump with its ventral location relative to the SMV was 2.7 mm (1.0–5.5 mm), the median of the actual length of the artery stump was 10.0 (6.7–21.3 mm) ($p < 0.001$). The median of the expected length of the ileocolic artery stump with its dorsal location relative to the SMV was 8.5 mm (6.7–11.7 mm), the median of the actual length of the artery stump was 6.0 mm (2.0–11.2mm) ($p = 0.650$). At the same time, significant differences were noted when comparing the expected and actual lengths of the ileocolic artery stump in patients with ventral artery location during D2 lymph node dissection, and in patients with dorsal artery course during D3 lymph node dissection (Table 1).

The distribution of data on the actual length of the ileocolic artery depending on its location from the SMV in the groups of patients with D2 and D3 lymph node dissection is shown in Figures 5 and 6. With the ventral location of the ileocolic artery relative to the SMV in patients with D2 lymph node dissection, the median of the actual length of the artery was 14.3 mm (8–25.6 mm), with D3 lymph node dissection of 7.6 mm (3.3–11.1 mm) ($p = 0.005$). With a dorsal arrangement of the ileocolic artery relative to SMV in patients with D2 lymph node dissection, the median actual length of the artery was 8.8 mm (4.9–16.2 mm), with D3 lymph node dissection — 3.9 mm (1–6.9 mm) ($p = 0.004$).

In the group of patients with ventral ileocolic artery, the median of the actual length of the artery stump during laparoscopic surgeries was 10.9

Table 1. *Comparison of the expected and actual lengths of the stump of the ileocolic artery with its ventral and dorsal location*

Location of a. ileocolica relative to SMV	Lymph dissection	Expected length of the stump a. ileocolica, mm	Actual length of the stump a. ileocolica, mm	*p*
Ventral (*n* = 38)		**2.7 (1.0–5.5)**	**10.0 (6.7–21.3)**	**< 0.001**
	D2 (*n* = 22)	2.6 (1–4.9)	14.3 (7.9–25.5)	< 0.001
	D3 (*n* = 16)	2.8 (1.4–6.8)	7.6 (3.2–11.1)	0.47
Dorsal (*n* = 44)		**8.5 (6.7–11.7)**	**6.0 (2.0–11.2)**	**0.65**
	D2 (*n* = 18)	10.3 (6.9–12.9)	8.8 (4.9–16.2)	0.727
	D3 (*n* = 26)	7.9 (6.4–10.3)	3.9 (1–6.8)	0.004

mm (6.6–20.9 mm), with open surgeries — 9 mm (7.9–27.4) (p = 0.6). In patients with a dorsal location of the ileocolic artery, the median of the actual length of the artery stump during laparoscopic procedures was 5.3 mm (1.7–10.9 mm), with open — 6.6 mm (5.4–11.6) (p = 0.5).

The right colic artery, independently extending from the SMA, was detected according to the CT data in 18 (21.9%) of 82 patients. The ventral location of the right colic artery relative to the SMV was noted in 16 out of 18 patients (88.9%), the dorsal location — in 2 (11.1%, 2/18) patients. The results obtained were fully confirmed by intraoperative data. With the ventral location of the artery relative to the SMV, the median of the expected length of the stump of the right colic

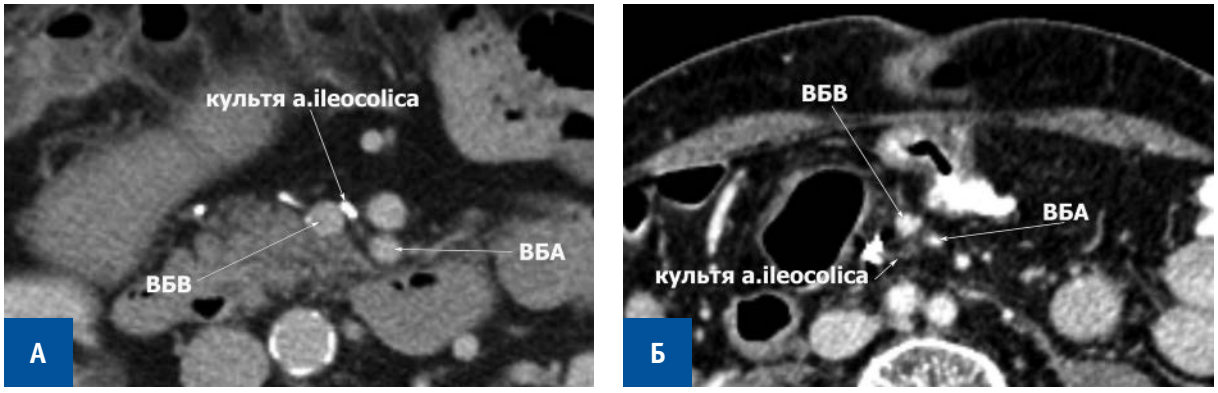

Figure 2. *A) CT image of the stump of the ileocolic artery with the artery located ventrally relative to the SMV (axial plane); Б) CT image of the stump of the ileocolic artery with the artery located ventrally relative to the SMV(axial plane)*

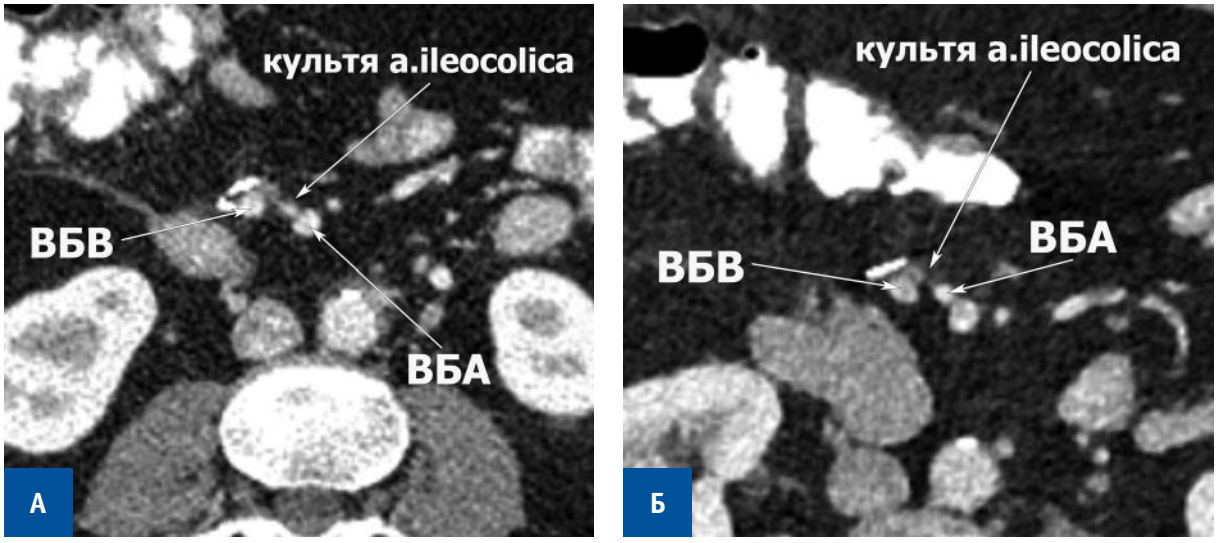

Figure 3. *Change in the appearance of the stump of the ileocolic artery on CT in dynamics. A) CT 1 month after surgery. The artery stump is visualized as a fibrotic line with fuzzy contours (axial plane); Б) CT1 year 8 months after surgery. In dynamics, there is a decrease of the thickness of the stump of the ileocolic artery and an increase in the clarity of its contours (axial plane)*

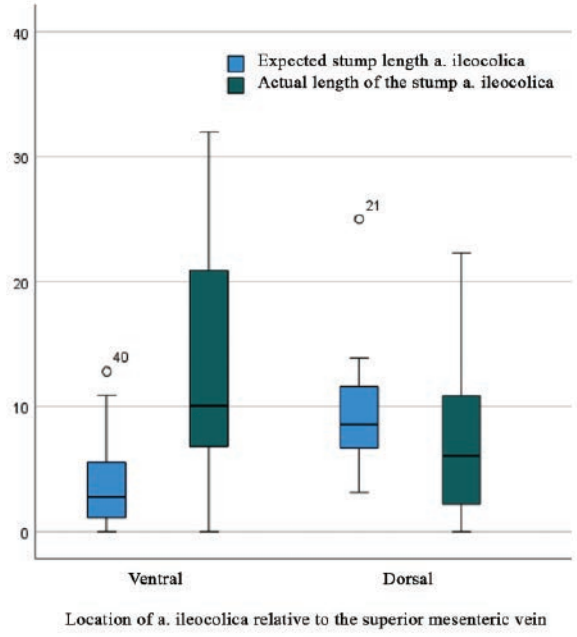

Figure 4. *Distribution of data on the expected and actual lengths of the stump of the ileocolic artery with the ventral and dorsal location of the artery*

artery was 5.2 mm (0–8.3 mm), the median of the actual length of the stump of the artery was 18.1 (2.9–29 mm) (p = 0.33). With the dorsal location of the right colic artery, the assessment was not carried out due to the small number of cases. We found a weak inverse correlation (-0.24) between the length of the ileocolic artery stump and the number of lymph nodes detected after surgery (p = 0.035) (Fig. 7).

When analyzing the relationship between the actual length of the ileocolic artery stump, the volume of blood loss during surgery, the time of surgery and the hospital-stay, a moderate inverse correlation (-0.357) was found between the actual length of the artery stump and the time of surgery, while the shorter the length of the artery stump, the longer the surgery time (p < 0.001).

When assessing postoperative morbidity, according to the Clavien-Dindo scale, their overall rate was 24.4% (20 out of 82 patients). Complications of the I degree were recorded in 14 (17%) patients out of 82, II degree — in one patient (1.2%, 1/82), III degree — in 5 patients (6.1%, 5/82). There were no complications of IV-V degree. Complications were mainly caused by changes in the area of the postoperative wound (5 patients) and intestinal obstruction (5 patients). In addition, complications were identified: perforation of the small intestine in combination with peritonitis, postoperative pancreatitis and severe anemia (1), subcutaneous eventration of the loop of the small intestine into the drainage hole (1), thrombogenic condition (1), combination of external duodenal fistula, acute postoperative pancreatitis

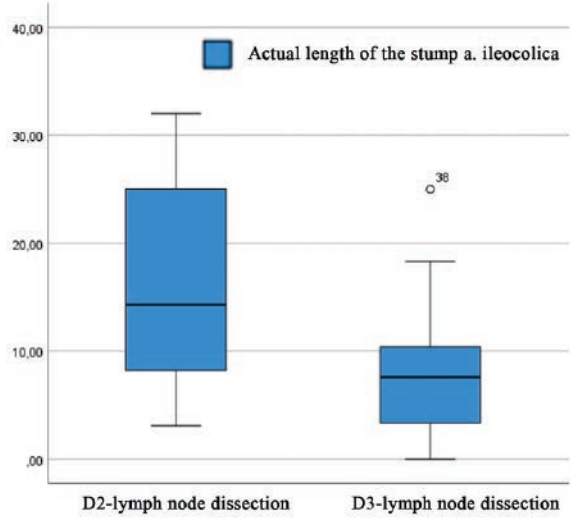

Figure 5. *Distribution of data on the actual length of the stump of the ileocolic artery with its ventral location relative to the SMV in groups of patients with D2- and D3-lymphadenectomy*

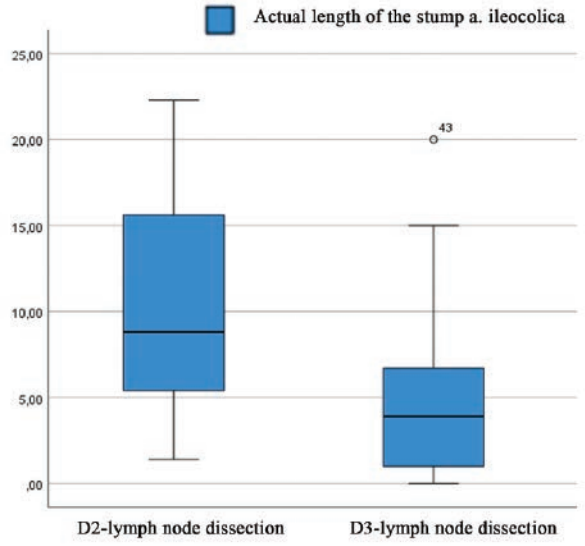

Figure 6. *Distribution of data on the actual length of the stump of the ileocolic artery when it is located dorsally relative to the SMV in groups of patients with D2- and D3lymphadenectomy*

and acute posthemorrhagic anemia (1), acute postoperative pancreatitis (1), areas of fluid collection in the area of the mesentery root of the small intestine and along the anterior renal fascia on the right (1), anemia (1), bleeding in the mesentery of the large intestine and perinephral tissue in the bed of the removed tumor (1). In statistical analysis, we assessed the relationship between the presence/absence of complications (complications of I-III degree were combined) and the actual length of the ileocolic artery stump, while patients were divided into groups depending on the length of the artery stump: 0–2 mm, 2–5 mm, 5–10 mm and more than 10 mm. When comparing the actual length of the ileocolic artery stump and the presence of complications according to the Clavien-Dindo classification, significant differences were revealed. It should be noted that the most common complications occurred in the group of patients with an actual ileocolic artery stump length of less than 2 mm (Table 2). In the structure of complications in patients with a stump length of less than 2 mm, degree I complications amounted to 75% (3 — changes in the area of the postoperative wound, 3 — dynamic intestinal obstruction), degree III — 25% (1 — perforation, peritonitis, pancreatitis, severe anemia; 1 — subcutaneous eventration of the loop of the small intestine into the drainage hole).

Lesion of gastrocolic trunk of Henleduring surgery was recorded in 1 (1.2%) of 82 patients with an actual ileocolic artery stump length of 2.1 mm.

DISCUSSION

TME has proven to be a reliable method of standardizing surgery for colon cancer. However, there is debate regarding high vascular ligation and optimal volume of lymph dissection in RCC. In largestudies on D3 lymph node dissection, the lesion of apical lymph nodes is up to 5% [20–22]. At the same time, according to Spasojevich et al., the number of removed lymph nodes is significantly higher in the dorsal location of the ileocolic artery relative to the SMV than in the ventral one, which emphasizes the need to adapt high vascular ligation to these anatomical variants [23]. The results we obtained regarding the anatomy of the

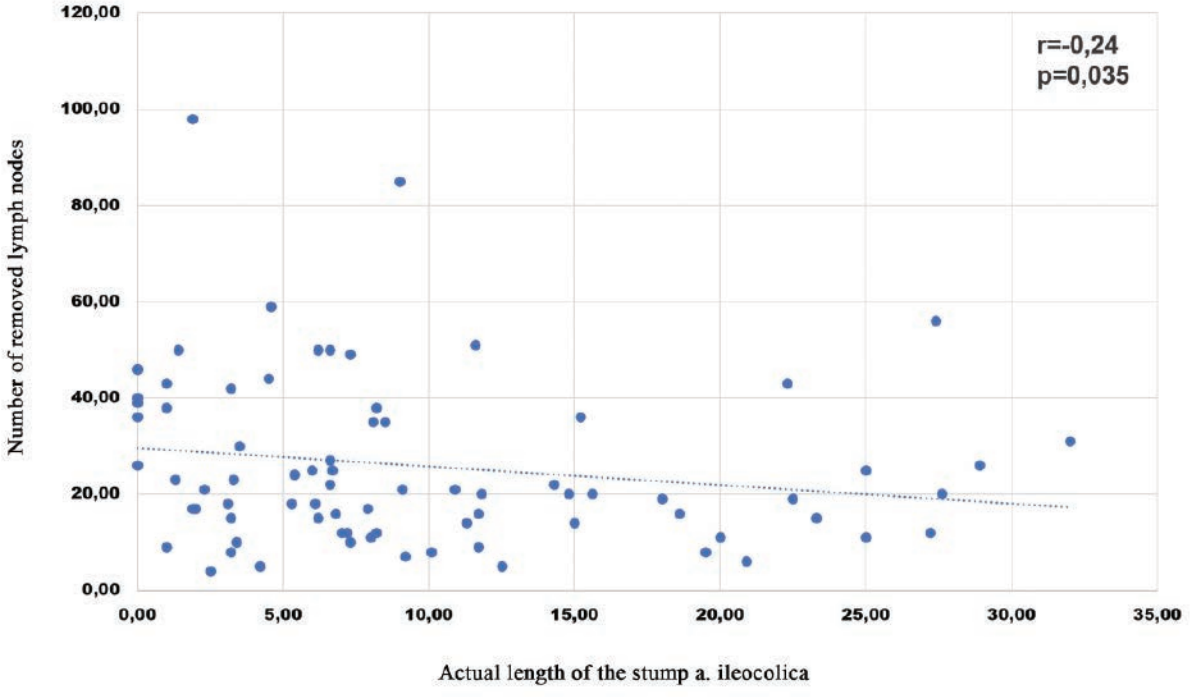

Figure 7. *Assessment of the correlation between the length of the stump of the ileocolic artery and the number of removed lymph nodes*

Table 2. *Complications in patients with different actual lengths of the ileocolic artery stump*

		The actual length of the ileocolic artery stump				Total
		Less than 2 mm	Between 2 and 5 mm	Between 5 and 10 mm	Over 10 mm	
Complications	Absent	5 8.1%	10 16.1%	21 33.9%	26 41.9%	62 100.0%
	Present	8 40.0%	3 15.0%	4 20.0%	5 25.0%	20 100.0%
Total		13 15.9%	13 15.9%	25 30.5%	31 37.8%	82 100.0%

ileocolic and right colon arteries correspond to the literature data. In the largest meta-analysis published by Negoi, the ventral location of the ileocolic artery relative to the SMV was revealed in 42.6% of cases, the dorsal location of the ileocolic artery relative to the SMV — in 57.4% of cases, the ventral location of the right colic artery relative to the SMV — in 89.4% of cases, the dorsal location of the right colic artery relative to the SMV — in 10.6% of cases.

The right colic artery, independently extending from the SMA, is present in about 23.8–43% of patients and is almost always located ventral to the SMV [19,24].

More than 10 years have passed since the first publication on the assessment of the level of vascular ligation after RHCE, according to CT data. However, international studies on this topic are few, and Russian publications, as far as we know, are missing. In this study, the ileocolic stump was visualized in all patients, with the exception of cases of localization of the surgical clip along the contour of the SMA. The stump of the right colic artery was determined in all patients in whom the artery was detected before surgery. In particular, the image of the stump of the main artery was obtained during repeated CT performed on average more than a year after surgery. We did not quantify the parameters of the stump of the feeding artery later. However, in a number of patients, a decrease in its width and greater clarity of contours were noted during repeated CTs. In this regard, the study by Munkendal (2019) is interesting, in which the length of the ileocolic artery stump was compared in 2 days and 1 year after surgery in patients with tumors of the right and left colon. A year after surgery, the vessel stump was visualized in 81% of cases (38 out of 47 patients). According to the type of stump, the arteries were divided into three groups: a normal vessel, a thrombosed vessel and a fibrous line. In about a third of cases, the stump was classified as a thrombosed vessel or fibrous line, and in these groups, the length of the stump was approximately 13% less in 1 year after surgery than in 2 days after surgery [25]. It should be noted that, in our opinion, the presence of metal clips in the artery stump facilitates its identification, despite the presence of artifacts. In the absence of metal clip, it is hard to identify the distal point of the artery stump, which makes it difficult to measure it. In the studies concerning the assessment of the expected and actual stump lengths of the feeding artery, the measurement of the expected stump length is carried out from the origin area to the right contour of the SMV, which corresponds to D2 lymph dissection [19,26,27]. A feature of our study is the measurement of the expected length of the stump of the ileocolic artery, depending on the course of the artery relative to the SMV. When performing TME with a high ligation of the ileocolic artery, the treatment of the latter is performed taking into account its location in relation to the SMV: in the posterior — along the lateral, in the ventral — along its medial edge. In this study, the median of the expected length of the ileocolic artery stump (2.7 mm) with its ventral location was significantly less than the actual (10 mm) ($p < 0.001$). With the dorsal location of the artery, the median of the expected stump length (8.5 mm) was greater than the actual length (6.0 mm), which is probably due to the traction of the artery during surgery

when its clipping. However, the differences were not statistically significant (p = 0.650). In addition, we found significant differences when comparing the expected and actual lengths of the ileocolic artery stump in D2-lymph node dissection in patients with ventral artery (p < 0.001) and D3-lymph node dissection in patients with dorsal artery (p < 0.004). No significant differences were found when comparing the expected and actual stump lengths of the right colic artery. We also compared the actual length of the ileocolic artery stump with its ventral and dorsal location relative to the SMV in groups with D2 and D3 lymph node dissection. The actual stump length of the ileocolic artery was significantly shorter in patients with D3 lymph node dissection with both ventral (7.6 mm) and dorsal artery location relative to the SMV (3.9 mm) compared with patients with D2 lymph node dissection (14.3 mm and 8.8 mm, respectively).

In previously published studies, the actual length of the ileocolic artery stump after standard RH was 28 mm and was greater than expected (14.4–18.1) [19,26]. Thus, the actual length of the ileocolic artery stump in our study was shorter for both patients with D3 and D2 lymph node dissection. In the study by Livadaru (2019), the actual length of the ileocolic artery stump in patients after TME with high vascular ligation was 16.97 ± 4.77 mm, after standard surgery — 49.93 ± 20.29 mm [27].

When comparing the data on the actual length of the ileocolic artery stump during laparoscopic and open surgeries, its median was comparable both with the ventral location of the artery (10.9 mm and 9 mm, respectively) and with its dorsal location (5.3 mm and 6.6 mm). The results were not significant in both groups. Similar results were obtained in the study by Lygre, K.B. (2024): when analyzing the data of 20 patients, no significant differences were found when comparing the length of the ileocolic artery stump during open and laparoscopic surgeries (on average 4.1 mm, p = 0.996) [28].

In a number of international studies, the length of the stump of the feeding artery was compared with the number of lymph nodes and the data of the resection plane of the pathomorphological specimen. In the study by Spasojevich (2011), no significant differences were found between the actual length of the ileocolic artery stump and the number of removed lymph nodes [26]. In his study, Kaye (2015) revealed significant variability in the length of the actual ileocolic artery stump, and those results correlated with the pathoanatomical data on the classification of postresection specimens, which showed large differences in the plane and volume of surgical resection in RCC [19].

In the previously noted study by Livadaru (2019) in the group of patients after TMCE with high vascular ligation, the average number of isolated lymph nodes was 34.83 ± 16.75 mm, and an inverse correlation of medium degree (–0.40) with the actual length of the artery stump (p = 0.032) was revealed. Similarly, the significance remained for the length of the resected sample with a moderate inverse correlation (0.44); at the same time, the longer the sample length, the shorter the stump length (p = 0.016) [27].

To date, only one study has revealed a relationship between the length of the stump of the feeding artery and the risk of locoregional recurrence in colon cancer. In the study by Livadaru (2022), a postoperative quality assessment scale was developed to predict the risk of locoregional recurrence in patients with large intestine tumors, including data on the actual length of the stump of the feeding artery. It was found that patients with locoregional recurrences had a significantly longer stump length of the feeding artery (50.77 ± 28.5 mm) compared with patients without recurrence (45.59 ± 28.1 mm) (p < 0.001) [29]. For the first time, we evaluated complications depending on the length of the ileocolic artery stump, depending on the level of lymph node dissection and the location of blood vessels in relation to SMV. In our study, the largest number of complications was recorded in the group of patients with a stump length of the ileocolic artery less than 2 mm.

In studies comparing TCME with standard surgery, a greater number of complications in TCME were noted [30,31]. Dissection at the root of the superior mesenteric artery poses a risk of lesion of the abdominal nerves, which leads to refractory diarrhea [30]. A significantly greater number of spleen and SMV injuries correlate with central vascular ligation [31], and the high variability of venous collaterals forming the gastrointestinal trunk as per Henle increases the risk of hemorrhages [32].

CONCLUSION

Measuring the length of the stump of the feeding artery during CT is a simple and reproducible method for evaluating the quality of surgery. The data obtained by us indicate the expediency of estimating the length of the ileocolic artery stump, depending on its location relative to the SMV, which takes into account the peculiarities of artery treatment during surgery. In this study, the length of the ileocolic artery stump measured by CT was significantly shorter in patients in the group with D3 lymph node dissection compared with the group of patients with D2 lymph node dissection, which confirms the assumption that the actual length of the stump may be an indicator of the level of ligation of the main arteries and indirectly the volume of lymph node dissection in RH. Further studies with a large number of observations are needed to confirm the hypothesis of measuring the length of the stump of the feeding arteries as a marker of the volume of the surgery performed, as well as to determine the significance of these data in oncological surgery.

AUTHORS CONTRUBUTION

Collection and processing of the material, statistical processing, writing of the text: *Anna A.Kholeva*

Concept and design of the study, analysis of the study, writing of the text: *Aleksey A. Nevolskikh*

Analysis of the study, writing of the text: *Tatev A. Agababian*

Collection and processing of the material: *Violetta A. Avdeenko*

Analysis of the study, editing: *Sergey A. Ivanov, Andrey D. Kaprin*

INFORMATION ABOUT THE AUTHORS (ORCID)

Anna A. Kholeva — 0000-0003-3635-8162.

Tatev A. Agababian — 0000-0002-9971-3451

Aleksey A. Nevolskikh — 0000-0001-5961-2958

Violetta A. Avdeenko — 0000-0002-2678-016X

Sergey A. Ivanov — 0000-0001-7689-6032

Andrey D. Kaprin — 0000-0001-8784-8415

REFERENCES

1. International Agency for Research on Cancer [Электронный ресурс]. Режим доступа: http://globocan.iarc.fr/Pages/fact_sheets_population.aspx International Agency for Research on Cancer [Electronic resource] http://globocan.iarc.fr/Pages/fact_sheets_population.aspx.

2. Hemminki K, Santi I, Weires M, et al. Tumor location and patient characteristics of colon and rectal adenocarcinomas in relation to survival and TNM classes. *BMC Cancer*. 2010 Dec 21;10:688. doi: 10.1186/1471-2407-10-688 PMID: 21176147; PMCID: PMC3022888

3. Mangone L, Pinto C, Mancuso P, et al. Colon cancer survival differs from right side to left side and lymph node harvest number matter. *BMC Public Health*. 2021;21:906. doi: 10.1186/s12889-021-10746-4

4. Wang CB, Shahjehan F, Merchea A, et al. Impact of tumor location and variables associated with overall survival in patients with colorectal Cancer: a Mayo Clinic Colon and Rectal Cancer registry study. *Front Oncol*. 2019;9:76. doi: 10.3389/fonc.2019.00076.

5. Warschkow R, Sulz MC, Marti L, et al. Better survival in right-sided versus left-sided stage I-III colon cancer patients. *BMC Cancer*. 2016;16(1):554. doi: 10.1186/s12885-016-2412-0

6. Ministry of Health of the Russian Federation. Clinical recommendations. Colon cancer. [Electronic resource]. Rubricator of clinical recommendations. URL: https://cr.minzdrav.gov.ru/schema/396_3 (in Russ.).

7. Hohenberger W, Weber K, Matzel K, et al. Standardized surgery for colonic cancer: complete mesocolic excision and central ligation--technical notes and outcome. *Colorectal Dis*. 2009 May;11(4):354–64; discussion 364-5. doi: 10.1111/j.1463-1318.2008.01735.x Epub 2009 Nov 5. PMID: 19016817;

8. Tejedor P, Francis N, Jayne D, et al. Consensus statements on complete mesocolic excision for right-sided

colon cancer—technical steps and training implications. *Surg Endosc*. 2022;36:5595–5601. doi: 10.1007/s00464-021-08395-0
9. NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines) Colon Cancer Version 3.2023 — September 21, 2023. https://www.nccn.org/professionals/physician_gls/pdf/colon.pdf
10. Argilés G, Tabernero J, Labianca R, et al. ESMO Guidelines Committee. Localised colon cancer: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol*. 2020 Oct;31(10):1291–1305. doi: 10.1016/j.annonc.2020.06.022 Epub 2020 Jul 20. PMID: 32702383
11. Benz S, Tannapfel A, Tam Y, et al. Proposal of a new classification system for complete mesocolic excison in right-sided colon cancer. *Tech Coloproctol*. 2019;23:251–257. doi: 10.1007/s10151-019-01949-4
12. Watanabe T, Itabashi M, Shimada Y, et al. Japanese Society for Cancer of the Colon and Rectum (JSCCR) Guidelines 2014 for treatment of colorectal cancer. *Int J Clin Oncol*. 2015;20:207–239. doi: 10.1007/s10147-015-0801-z
13. Søndenaa K, Quirke P, Hohenberger W, et al. The rationale behind complete mesocolic excision (CME) and a central vascular ligation for colon cancer in open and laparoscopic surgery: proceedings of a consensus conference. *Int J Colorectal Dis*. 2014;29:419–428. PMID: 24477788. doi: 10.1007/s00384-013-1818-2
14. Hashiguchi Y, Muro K, Saito Y, et al. Japanese Society for Cancer of the Colon and Rectum. Japanese Society for Cancer of the Colon and Rectum (JSCCR) guidelines 2019 for the treatment of colorectal cancer. *Int J Clin Oncol*. 2020;25(1):1–42. doi: 10.1007/s10147-019-01485-z
15. West NP, Hohenberger W, Weber K, et al. Complete mesocolic excision with central vascular ligation produces an oncologically superior specimen compared with standard surgery for carcinoma of the colon. *J Clin Oncol*. 2010;28:272–278 PMID: 19949013. doi: 10.1200/JCO.2009.24.1448
16. Tuktagulov N.V., Sushkov O.I., Muratov I.I., et al. The choice of the volume of lymph node dissection in cancer of the right half of the colon (literature review). (review). *Koloproktologia*. 2018;(3):84–93. (In Russ.). doi: 10.33878/2073-7556-2018-0-3-84-93
17. West NP, Kobayashi H, Takahashi K, et al. Understanding optimal colonic cancer surgery: comparison of Japanese D3 resection and European complete mesocolic excision with central vascular ligation. *J Clin Oncol*. 2012;30:1763–1769 [PMID: 22473170 DOI: 10.1200/JCO.2011.38.3992]
18. Munkedal DLE, Rosenkilde M, Nielsen DT, et al. Radiological and pathological evaluation of the level of arterial division after colon cancer surgery. *Colorectal Dis*. 2017 Jul;19(7):O238-O245. doi: 10.1111/codi.13756 PMID: 28590033.
19. Kaye TL, West NP, Jayne DG, et al. CT assessment of right colonic arterial anatomy pre and post cancer resection — a potential marker for quality and extent of surgery? *Acta Radiol*. 2016 Apr;57(4):394–400. doi: 10.1177/0284185115583033 Epub 2015 May 4. PMID: 25940063.
20. Kanemitsu Y, Komori K, Kimura K, et al. D3 Lymph Node Dissection in Right Hemicolectomy with a No-touch Isolation Technique in Patients With Colon Cancer. *Dis Colon Rectum*. 2013;56(7):815–24. doi: 10.1097/DCR.0b013e3182919093
21. Kotake K, Mizuguchi T, Moritani K, et al. Impact of D3 lymph node dissection on survival for patients with T3 and T4 colon cancer. *Int J Colorectal Dis*. 2014;29(7):847–52. doi: 10.1007/s00384-014-1885-z
22. Xu L, Su X, He Z, et al. RELARC Study Group. Short-term outcomes of complete mesocolic excision versus D2 dissection in patients undergoing laparoscopic colectomy for right colon cancer (RELARC): a randomised, controlled, phase 3, superiority trial. *Lancet Oncol*. 2021;22(3):391–401. doi: 10.1016/S1470-2045(20)30685-9
23. Spasojevic M, Stimec BV, Dyrbekk AP, et al. Lymph node distribution in the d3 area of the right mesocolon: implications for an anatomically correct cancer resection. A postmortem study. *Dis Colon Rectum*. 2013;56(12):1381–7. doi: 10.1097/01.dcr.0000436279.18577.d3
24. Negoi I, Beuran M, Hostiuc S, et al. Surgical Anatomy of the Superior Mesenteric Vessels Related to Colon and Pancreatic Surgery: A Systematic Review and Meta-Analysis. *Sci Rep*. 2018 Mar 8;8(1):4184. doi: 10.1038/s41598-018-22641-x PMID: 29520096; PMCID: PMC5843657.
25. Munkedal DLE, Rosenkilde M, Nicholas P, et al. (2019) Routine CT scan one year after surgery can be used to estimate the level of central ligation in colon cancer surgery. *Acta Oncologica*. 58:4, 469-471, DOI: 10.1080/0284186X.2019.1566770
26. Spasojevic M, Stimec BV, Gronvold LBm, et al. The anatomical and surgical consequences of right colectomy for cancer. *Dis Colon Rectum*. 2011 Dec;54(12):1503–9. doi: 10.1097/DCR.0b013e318232116b PMID: 22067178
27. Livadaru C, Morarasu S, Frunza TC, et al. Postoperative computed tomography scan — reliable tool for quality assessment of complete mesocolic excision. *World J Gastrointest Oncol*. 2019 Mar 15;11(3):208–226. doi: 10.4251/wjgo.v11.i3.208 PMID: 30918594; PMCID: PMC6425332.
28. Lygre KB, Eide GE, Liedenbaum MH, et al. Short and equal vascular stump length after standardized laparoscopic and open surgery with central lymphadenectomy for right-sided colon cancer. *Br J Surg*. 2024 Jan

3;111(1):znad410. doi: 10.1093/bjs/znad410 PMID: 38064678; PMCID: PMC10771266.
29. Livadaru C, Moscalu M, Ghitun FA, et al. Postoperative Quality Assessment Score Can Select Patients with High Risk for Locoregional Recurrence in Colon Cancer. *Diagnostics (Basel)*. 2022 Feb 1;12(2):363. doi: 10.3390/diagnostics12020363 PMID: 35204454; PMCID:
30. Bertelsen CA, Neuenschwander AU, Jansen JE, et al. Copenhagen Complete Mesocolic Excision Study (COMES); Danish Colorectal Cancer Group (DCCG). Short-term outcomes after complete mesocolic excision compared with 'conventional' colonic cancer surgery. *Br J Surg*. 2016;103:581–589. PMID: 26780563 DOI: 10.1002/bjs.10083
31. Bertelsen CA. Complete mesocolic excision an assessment of feasibility and outcome. *Dan Med J*. 2017; 64. PMID: 28157065
32. Wang C, Gao Z, Shen K, et al. Safety, quality and effect of complete mesocolic excision vs non-complete mesocolic excision in patients with colon cancer: a systemic review and meta-analysis. *Colorectal Dis*. 2017;19:962–972. PMID: 28949060 DOI:10.1111/codi.13900