



MEDICAL UNIVERSITY “PROF. PARASKEV  
STOYANOV” OF VARNA  
FACULTY OF MEDICINE  
DEPARTMENT OF GENERAL AND OPERATIVE  
SURGERY

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**ROLE OF VIRTUAL COLONOSCOPY IN  
MINIMALLY INVASIVE AND ROBOT-ASSISTED  
ONCOLOGICAL COLORECTAL SURGERY**

**AUTHOR’S DISSERTATION SUMMARY**

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# CONTENTS

## CONTENTS

CONTENTS.....	3
1. INTRODUCTION.....	6
2. PURPOSE AND TASKS .....	7
3. MATERIAL.....	8
3.1. General characteristics of the examined contingent.....	8
4. METHODS.....	17
4.1. Virtual colonoscopy of colorectal cancer and colorectal polyps.....	17
4.2. Fibrocolonoscopy of colorectal cancer and colorectal polyps .....	18
4.3. Statistical methods.....	18
5. RESULTS.....	19
5.1. Diagnostic role of virtual colonoscopy in colorectal cancer patients.....	19
5.2. Diagnostic role of virtual colonoscopy in colorectal polyp patients .....	27
5.3. Diagnostic role of virtual colonoscopy in other large bowel and extracolonic diseases..	33
5.4. Diagnostic role of virtual colonoscopy in staging the colorectal cancer patients .....	38
5.5. Diagnostic role of virtual colonoscopy in the choice of a surgical method .....	45
6. DISCUSSION.....	53
6.1. Diagnostic value of virtual colonoscopy in colorectal cancer patients .....	53
6.2. Diagnostic role of virtual colonoscopy in other large bowel and extracolonic diseases.....	62
6.3. Diagnostic role of virtual colonoscopy in the choice of a surgical method .....	66
7. CONCLUDING REMARKS.....	77
8. CONCLUSIONS.....	78
9. CONTRIBUTIONS .....	79
10. FUTURE DIRECTIONS .....	80
11. PUBLICATIONS.....	81
12. APPENDIX.....	82
13. GRATITUDES .....	84

## ABBREVIATIONS USED

AAAo	aneurysm of abdominal aorta
ADC	adenocarcinoma
AMI	arteria mesenterica inferior
AMS	arteria mesenterica superior
VCI	vena cava inferior
incl.	inclusive
VCS	virtual colonoscopy
VMI	vena mesenterica inferior
VMS	vena mesenterica superior
VP	vena portae
GIST	gastrointestinal stromal tumour
GIT	gastrointestinal tract
t.	town
RHC	right hemicolectomy
CO	conventional operation
CRC	colorectal carcinoma, colorectal cancer
LN	lymph node
LHC	left hemicolectomy
m.	month
MI	miniinvasive (minimally invasive)
ARR	anterior rectum resection
RLN	regional lymph nodes
SR	sigmoid colon resection
TR	transversum colon resection
cm	centimeter
UMHAT	University multiprofile hospital for active treatment
fig.	figure
FCS	fibrocolonoscopy
US\$	US dollars
CO <sub>2</sub>	carbon dioxide
kg	kilogram
CT	computed tomography
kV	kilo-volt
m	meter

mGy	milligray
min	minute(s)
mL	millilitre
mm	millimeter
sec	second
µm	micrometer
<sup>18</sup> F FDG	18F-fluorodeoxyglucose
ACD	arteria colica dextra
ACM	arteria colica media
ACS	arteria colica sinistra
AI	arteria ileocolica
AoA	aorta abdominalis
ARS	arteria rectalis superior
AS	arteria sigmoidalis
EEA	end-to-end anastomosis
ESGAR	European Society of Gastrointestinal and Abdominal Radiology
ESGE	European Society of Gastrointestinal Endoscopy
et al.	et alierte
IBD	inflammatory bowel disease
NOSES	Natural orifice specimen extraction surgery
PET/CT	Positron emission tomography/computed tomography
SIGGAR	Special interest group in gastrointestinal and abdominal radiology
TNM	TNM Classification of Malignant Tumours
WSES	World Society of Emergency Surgery

# 1. INTRODUCTION

Nowadays colorectal cancer continues to be the third commonly diagnosed malignant disease worldwide among males and the second one among females. Thanks to the interdisciplinary efforts of the world scientific community during the recent years, undoubted successes in terms of the early and more and more precise diagnosis of this socially significant disease have been achieved. One bears in mind not only the new laboratory parameters but also the uninterruptedly perfected modern apparatuses and methods for imaging diagnosis. We are the witness of the diversification of the endoscopic methods for preoperative diagnosis of the colon and rectum cancer, too. The implementation of the new technologies in this field has enabled the elaboration and the more and more mass introduction of the computed tomographic colonography also known as virtual colonoscopy. It deals with the usage of the computed tomography scan or nuclear magnetic resonance for obtaining the two- and tridimensional images of the whole large bowel aiming at its minimally invasive and structural evaluating and rapid imaging.

In the world literature, foreign publications occurred that juxtaposed a series of characteristics of the diagnostic value of the virtual colonoscopy and its precursor, the optical colonoscopy. Although it commonly deals with large-scale trials, usually, single aspects of these topical problems and at that, in heterogenous and difficultly comparable patients' samples are analyzed. Not only traditional methods of open surgery but also minimally invasive operative interventions in the form of laparoscopic and/or robot-assisted colorectal surgery are made use of.

These incompletenesses of the contemporary scientific knowledge gave us grounds to perform the present complex investigation in order to outline the concrete significance of the virtual colonoscopy when comparing it with the fibrocolonoscopy for the preoperative diagnosis of the colorectal oncological diseases and to contribute to the popularization of this comparatively new method in the Bulgarian clinical practice.

## 2. PURPOSE AND TASKS

The purpose of the dissertation work is to study the role of the virtual colonoscopy in the minimally invasive and robot-assisted oncological colorectal surgery.

For accomplishing this purpose, we set us the following **tasks**:

1. To study the diagnostic role of the virtual colonoscopy in colorectal cancer patients.
2. To study the diagnostic role of the virtual colonoscopy in colorectal polyp patients.
3. To analyze the additional diagnostic role of the virtual colonoscopy in large bowel and extracolonic diseases.
4. To analyze the application of the virtual colonoscopy in staging the colorectal cancer patients.
5. To analyze the application of the virtual colonoscopy in the choice of a surgical method.

### 3. MATERIAL

#### 3.1. General characteristics of the examined contingent

The study described is retrospective, observational, and monocentre. It was carried out within the structures of St. Marina University Hospital of Varna single joint-stock company. It covered the patients having undergone virtual and endoscopic colonoscopy from January 1, 2012 till December 31, 2021. The study was approved by decision No 115/March 31, 2022 of the Commission of Research Ethics (CRE) at the Medical University ‘Prof. Paraskev Stoyanov’ of Varna. The patients who have undergone virtual colonoscopy are the object of the investigation.

During a ten-year period (between January 1, 2012 and December 31, 2021), we retrospectively examined by means of virtual colonoscopy (VCS) a total of 1695 patients and by means of fibrocolonoscopy (FCS) - a total of 812 out of these patients. It deals with the patients hospitalized in the St. Marina University Hospital of Varna single joint-stock company on the occasion of colorectal symptoms. By using of VCS, 719 males aged between 19 and 94 years and 976 females aged between 20 and 90 years, while by using of FCS - 368 males aged between 21 and 94 years and 444 females aged between 21 and 89 years are examined. VCS was accomplished with SOMAOM double-energy scanner of Siemens firm (Germany) (Fig. 1).



*Fig. 1. SOMAOM double-energy scanner of Siemens firm (Germany)*

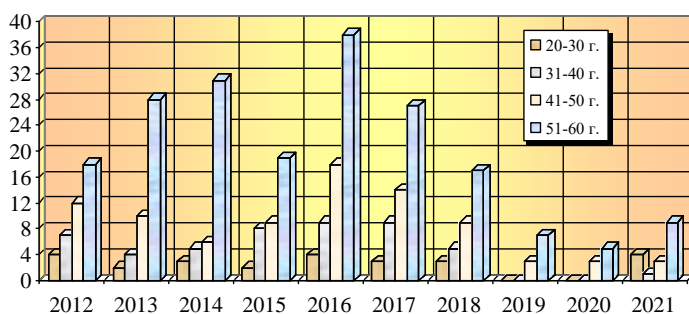




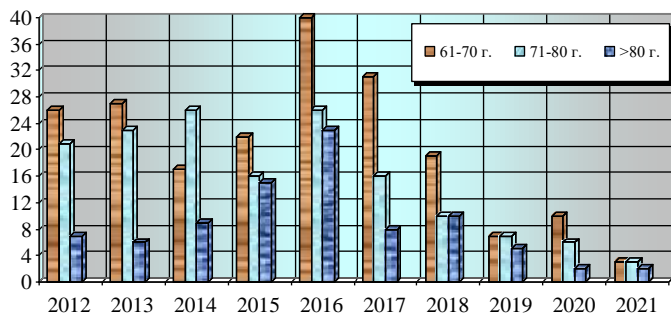
The optical colonoscopy or fibrocolonoscopy (FCS) was performed with Olympus EXERA II fibrocolonoscope (Fig. 2).

*Fig.2. Olympus EXERA II fibrocolonoscope*

The annual dynamics of male patients examined by means of VCS according to age is demonstrated in Fig. 3 and Fig. 4. The comparatively small number of the examined patients during the last three years is due to COVID 19 pandemic.



*Fig. 3. Annual dynamics of male patients examined by means of VCS aged between 19 and 60 years*

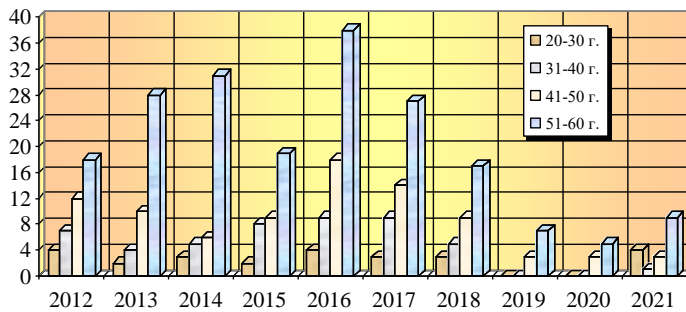


*Fig. 4. Annual dynamics of male patients examined by means of VCS aged over 61 years*

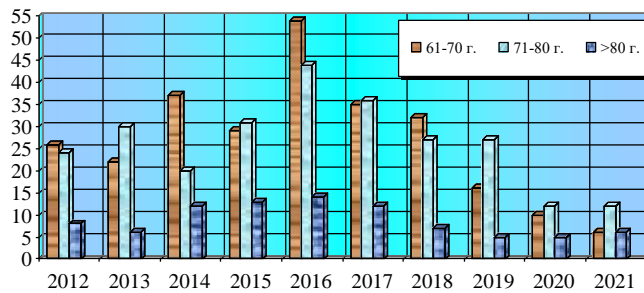
The total number of male patients is greatest in 2016 (129), in 2012 (104) and in 2013 (103). Most commonly, the male patients at the age groups between 61

and 70 years (197 patients or 27,40%) and between 51 and 60 years (166 patients or 23,09% of the cases) are examined.

The annual dynamics of female patients examined by means of VCS according to age can be seen in Fig. 5 and Fig. 6.



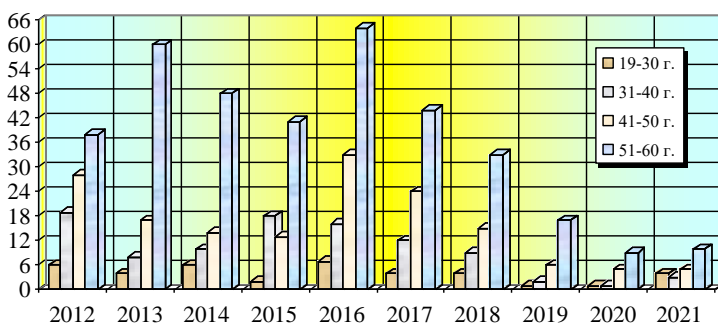
*Fig. 5. Annual dynamics of female patients examined by means of VCS aged between 20 and 60 years*



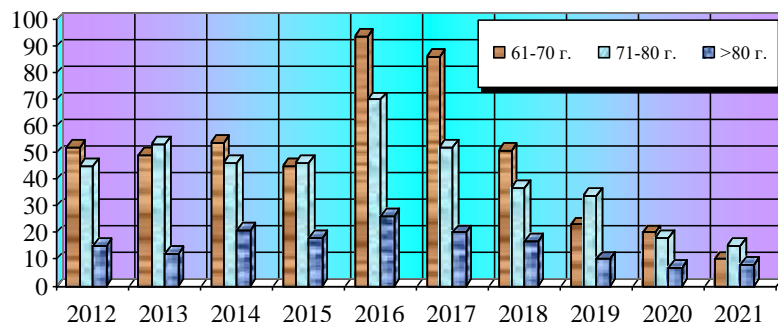
*Fig. 6. Annual dynamics of female patients examined by means of VCS aged over 61 years*

The total number of female patients is greatest in 2016 (181) and in 2017 (136) but smallest in 2020 (35) and in 2021 (40). Most commonly, the female patients at the age groups between 61 and 70 years (267 patients or 27,36%) and between 71 and 80 years (263 patients or 26,95% of the cases) are examined.

The annual dynamics of all the patients as a whole examined by means of VCS according to age is shown in Fig. 7 and Fig. 8.



*Fig. 7. Annual dynamics of all the patients examined by means of VCS aged between 19 and 60 years*

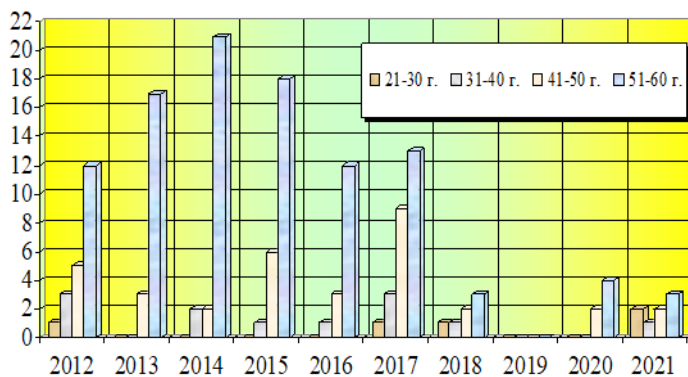


*Fig. 8. Annual dynamics of all the patients examined by means of VCS aged over 61 years*

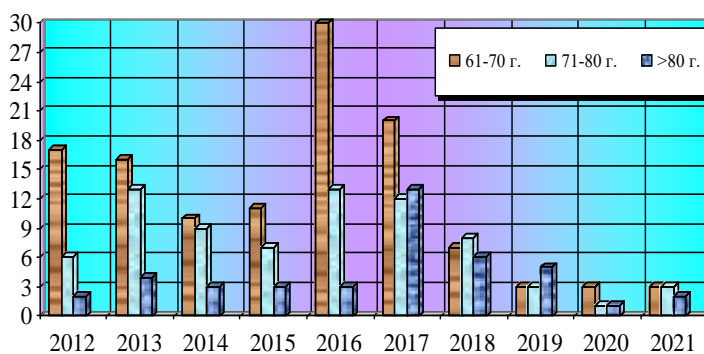
The total number of all the patients as a whole is greatest in 2016 (310 patients or 18,29%) and in 2017 (222 patients or 13,09% of the cases).

Most commonly, all the patients as a whole at the age groups between 61 and 70 years (464 patients or 27,37%) and between 71 and 80 years (416 patients or 24,54% of the cases) are examined.

The annual dynamics of male patients examined by means of FCS, too (out of the group examined by VCS) according to age is illustrated in Fig. 9 and Fig. 10. The comparatively small number of the examined patients during the last three years is due to COVID 19 pandemic.



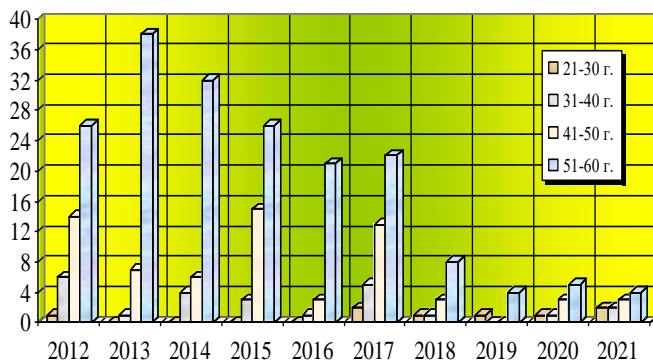
*Fig. 9. Annual dynamics of male patients examined by means of FCS aged between 21 and 60 years*



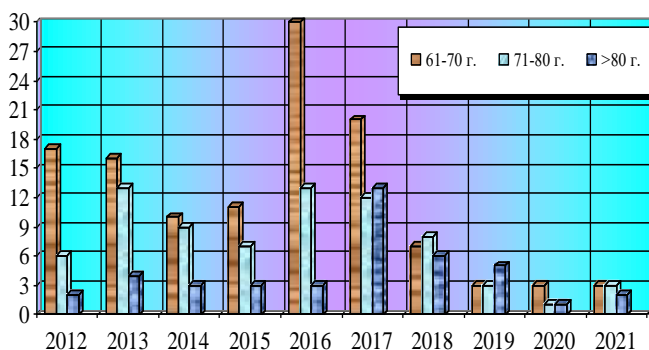
*Fig. 10. Annual dynamics of male patients examined by means of FCS aged over 61 years*

The total number of male patients is greatest in 2017 (61), in 2013 (59) and in 2016 (55). Most commonly, the male patients at the age groups between 61 and 70 years (120 patients or 32,61%) and between 51 and 60 years (83 patients or 22,55% of the cases) are examined.

The annual dynamics of female patients examined by means of FCS, too (out of the group examined by VCS) according to age is presented in Fig. 11 and Fig. 12.



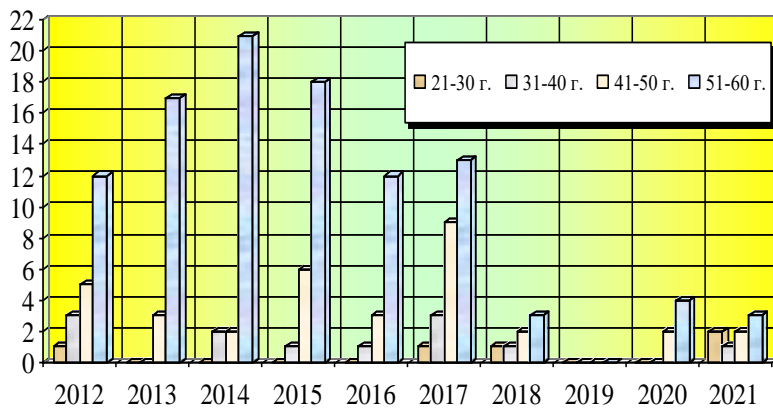
*Fig. 11. Annual dynamics of female patients examined by means of FCS aged between 21 and 60 years*



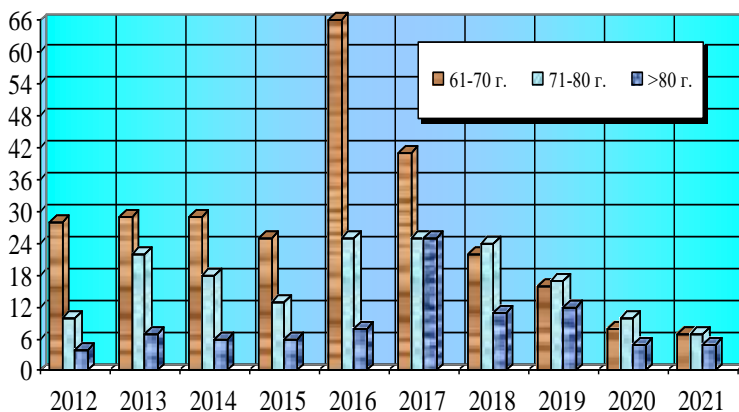
*Fig. 12. Annual dynamics of female patients examined by means of FCS aged over 61 years*

The total number of female patients is greatest in 2017 (72 or 8,83%) and in 2016 (69 or 8,46%) but smallest in 2021 (19 or 2,33%) and in 2020 (24 or 2,94% of the cases). Most commonly, the female patients at the age groups between 61 and 70 years (147 patients or 33,11%) and between 51 and 60 years (103 patients or 23,20% of the cases) are examined.

The annual dynamics of all the patients as a whole examined by means of FCS (out of the group examined by VCS) according to age is demonstrated in Fig. 13 and Fig. 14.



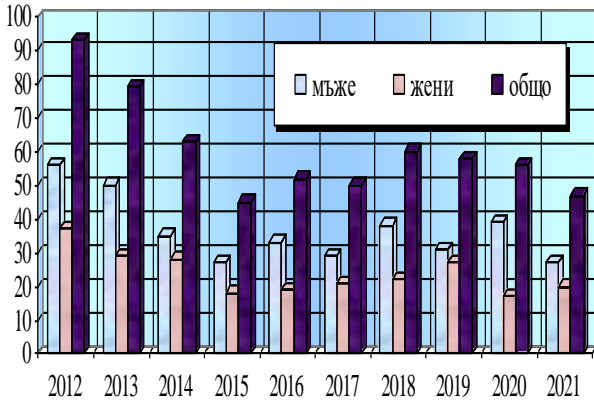
*Fig. 13. Annual dynamics of all the patients examined by means of FCS aged between 19 and 60 years*



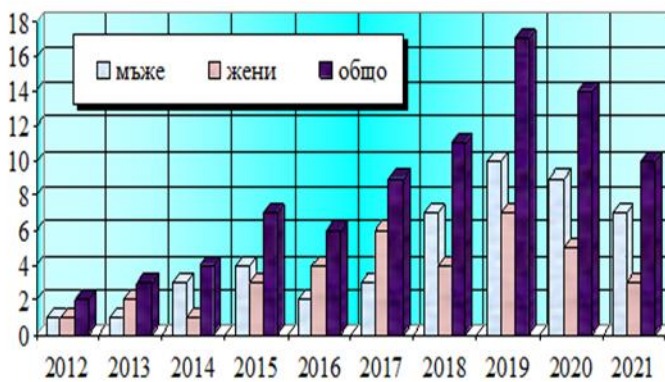
*Fig. 14. Annual dynamics of all the patients examined by means of FCS aged over 61 years*

Most commonly, all the patients as a whole at the age groups between 61 and 70 years (267 patients or 32,88%) and between 51 and 60 years (186 patients or 22,91% of the cases) are examined.

The operative treatment was carried out in 715 CRC patients as followed: open surgery - in 603, laparoscopic surgery - in 83 and robot-assisted surgery - in 29 patients. The annual dynamics of the open and laparoscopic operations is illustrated in Fig.15 and Fig. 16.

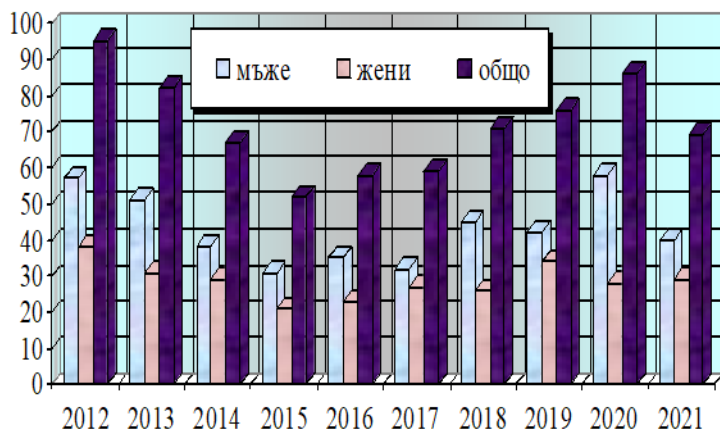


*Fig. 15. Annual dynamics of the open colorectal operations carried out in the First Clinic of Surgery*



*Fig. 16. Annual dynamics of the laparoscopic colorectal operations carried out in the First Clinic of Surgery*

Robot-assisted operation is performed in one male in 2019, in 10 males in 2020 and in six males in 2021 as well as in six females each in 2020 and in 2021. The annual dynamics of all the operations carried out on the occasion of CRC in the First Clinic of Surgery at St. Marina University Hospital of Varna single joint-stock company during the period between January 1, 2012 and December 31, 2021 is demonstrated in Fig. 17.



*Fig. 17. Annual dynamics of all the colorectal operations carried out in the First Clinic of Surgery*

During the last three years, there is an increase not only of the number but also of the relative share of the patients who have undergone minimally invasive operations on the account of the open operations.

A laparoscopic operation is performed in 41 patients (in 18,55%), a robot-assisted operation - in 29 patients (in 13,12%), while an open operation - in the rest 151 patients (in 68,33% of the cases) during this three-year period.



## **4. METHODS**

### **4.1. Virtual colonoscopy of colorectal cancer and colorectal polyps**

VCS represents the usage of the computed tomographic scanning or nuclear magnetic resonance for obtaining the two- and tridimensional images of the large bowel - from its lowest part (anus and rectum) to terminal ileum as it utilizes an expanded visualization technology and digital information storage that enables a minimally invasive structural evaluation and rapid imaging of the whole colon. The technique allows the assessment of the large bowel proximally from the obstructive lesions as well as of the extracolonic abdominal and pelvic organ pathologies.

VCS is accomplished in all the patients with Siemens SOMATOM Definition AS scanner according to the instructions of the manufacturer firm after the necessary preliminary patients' colon preparation.

The next procedures follow: large bowel insufflation, scanning of the obtained images, data interpretation such as detection, polyp characterization, data reading and computer recognition - diagnosis.

We accepted the following indications for the virtual colonoscopy - incomplete fibrocolonoscopy, positive fecal test for occult bleeding, familial burden for CRC and enhanced tumour marker, following-up of polyps larger than 6 mm, presence of symptoms suggesting the CRC, following-up after colon resection on the occasion of CRC as well as patients' refusal of FCS or with contraindications for FCS.

We accepted the following contraindications for the virtual colonoscopy - active colon inflammation such as diverticulitis, active stage of an inflammatory bowel syndrome, and toxic megacolon as well as syndromes of an acute surgical abdomen, accreted herniae, abdominal or pelvic operative intervention during the last 30 days, and allergy.

In all the patients with rectal cancer planned for operative treatment, additional imaging examinations such as chest computed tomography, pelvic

magnetic resonance imaging, abdominal ultrasonography, endorectal ultrasonography, positron emission tomography, etc. are timely performed.

## **4.2. Fibrocolonoscopy of colorectal cancer and colorectal polyps**

FCS is accomplished in all the patients by means of Olympus EXERA II fibrocolonoscope (Fig. 2) according to the instructions of the manufacturer firm after the necessary preliminary patients' colon preparation.

Modern fibrocolonoscopes are equipped with a camera, light guide and four working ports on the tip. The camera enables the high-resolution observation of the images on a video screen as well as image approximation and magnification. The four working channels include a flexible tip for overcoming the vaporous folds hampering the lesion visualization, colon insufflation, irrigation in the area of interest, aspiration in order not to overlook lesions below the fluid as well as insertion of biopsy or polypectomy clips and loops.

In the patients diagnosed with CRC and planned for operative treatment, additional examination with positron emission tomography (PET/CT) and in some of them with computed tomography (CT) is performed.

When examining the vascular anatomy of arteria mesenterica superior and arteria mesenterica inferior with their branches and corresponding venous vessels, we used Wang's classification for the left colon (Wang et al. 2018) and Henle's one for the right colon (Alsabilah et al., 2017; Ciocchi et al., 2021).

## **4.3. Statistical methods**

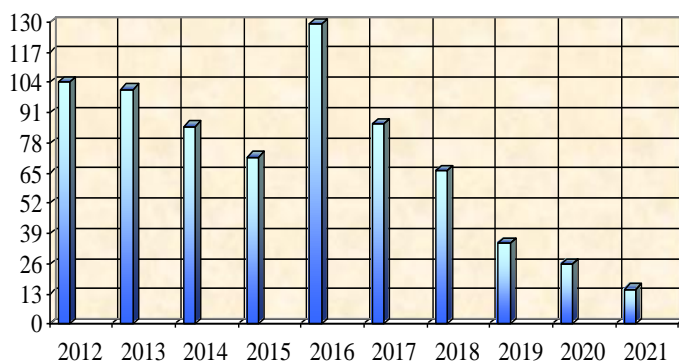
The results obtained by us were statistically processed by using of descriptive variation (Student-Fisher's test) and graphical analysis. The statistical reliability according to Student-Fisher's *t*-criterion was read at significance level of  $p < 0,05$ .

## 5. RESULTS

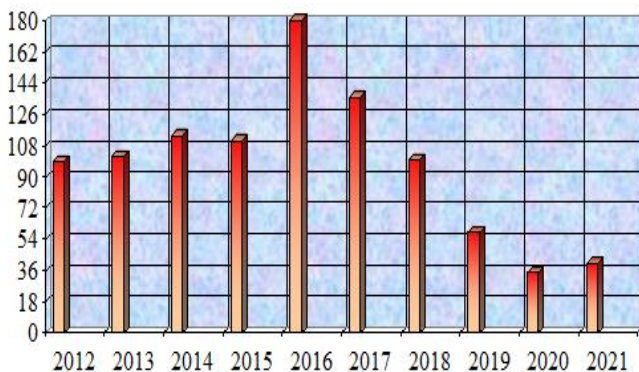
### 5.1. Diagnostic role of virtual colonoscopy in colorectal cancer patients

During a ten-year period, 1695 patients are examined by means of VCS. They are 719 males (42,42%) and 976 females (57,58%).

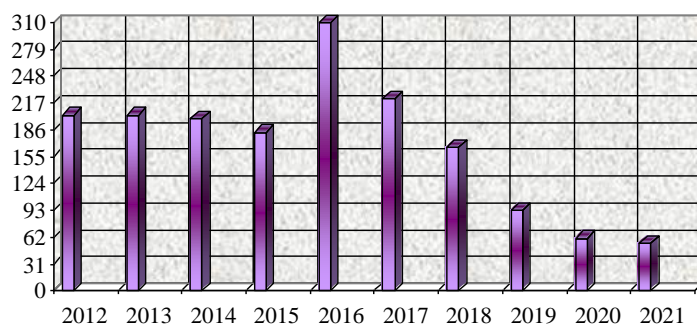
The annual dynamics of the number of the male patients, the female patients and all the patients as a whole examined by means of VCS is shown in Fig. 18, Fig. 19, and Fig. 20.



*Fig. 18. Annual dynamics of male patients examined by means of VCS*



*Fig. 19. Annual dynamics of female patients examined by means of VCS*



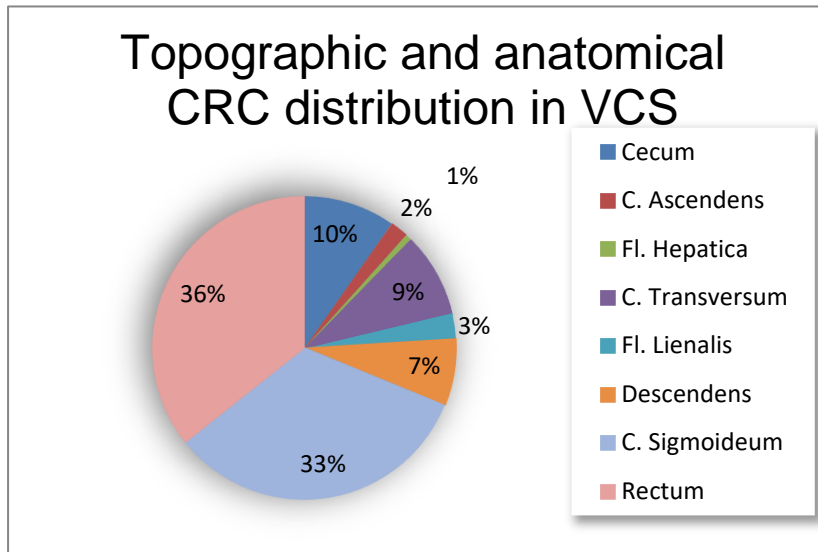
*Fig. 20. Annual dynamics of all the patients examined by means of VCS*

The annual dynamics of the relative share of the male patients, the female patients and all the patients as a whole examined by means of VCS is indicated in Table 1.

*Table 1. Annual dynamics of the relative share of the patients examined by means of VCS*

<b>Year</b>	<b>males</b>	<b>females</b>	<b>total</b>
<b>2012</b>	51,23	48,77	11,98
<b>2013</b>	49,75	50,25	11,98
<b>2014</b>	42,71	57,29	11,74
<b>2015</b>	39,34	60,66	10,80
<b>2016</b>	41,61	58,39	18,29
<b>2017</b>	38,74	61,26	13,10
<b>2018</b>	39,76	60,24	9,79
<b>2019</b>	37,67	62,37	5,49
<b>2020</b>	42,62	57,38	3,60
<b>2021</b>	27,27	72,73	3,24
<b>total</b>	42,42	57,58	100,00

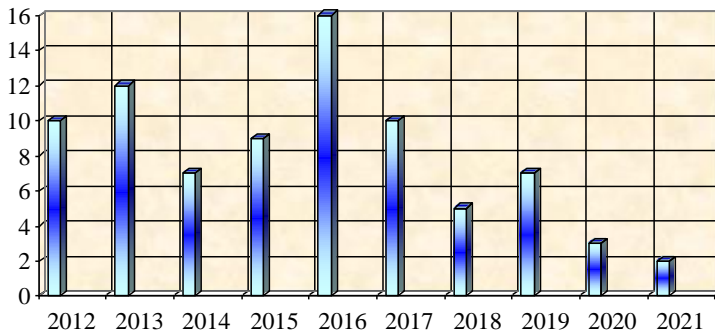
It can be seen that the relative share of the examined males is by a little bit greater than that of the examined females in 2012 only. The total ratio of the relative share of the females towards that of the males is 1,36. Its value is greatest in 2021 (2,68) but smallest in 2013 (1,01) only. Not only the number but also the relative share of the patients examined by means of VCS are greatest in 2016 (a total of 310 or 18,29% of the cases). All the colorectal cancers established are



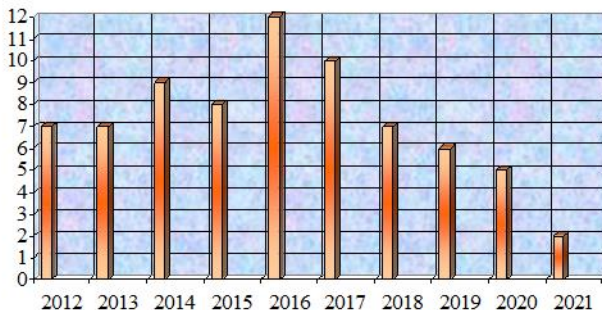
staged according to T-criterion of the International TNM classification. Their topographic and anatomical localization is presented in Fig. 21.

A total of 154 CRC patients are diagnosed by means of VCS, 81 males (4,78%) and 73 females (4,30%) presented in Fig. 22 and Fig. 23.

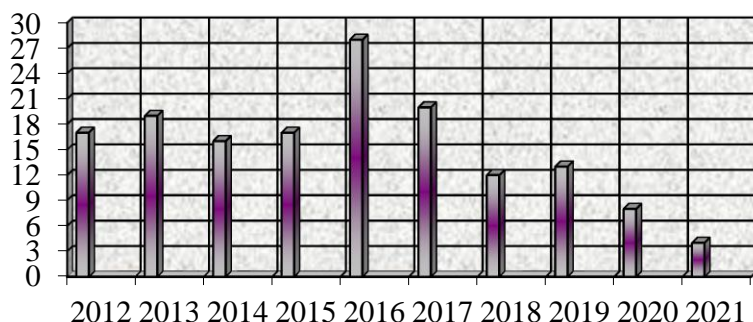
*Fig. 21. Topographic and anatomical CRC distribution in VCS*



*Fig. 22. Annual dynamics of male CRC patients diagnosed by means of VCS*



*Fig. 23. Annual dynamics of female CRC patients diagnosed by means of VCS*



*Fig. 24. Annual dynamics of All CRC patients diagnosed by means of VCS*

On Table 2 it can be seen that the total relative share of the males with CRC diagnosed by means of VCS is by 1,51 times greater than that of the females. The value of the relative share of the males with CRC diagnosed by means of VCS is greatest in 2019 but smallest in 2018 while that of the females is in 2020 and in 2021, respectively. The relative share of the males with CRC in 2019 is by 1,93 times greater than that of the females. During this period, a total of 88 patients with a synchronous colorectal tumour are diagnosed by means of VCS - 48 males (2,83%) and 40 females (2,36%).

Year	males	females	total
2012	9,62	7,07	8,37
2013	11,88	6,86	9,36
2014	8,24	7,89	8,04
2015	12,50	7,21	9,29
2016	12,40	6,63	9,03
2017	11,63	7,35	9,01
2018	7,58	7,00	7,23
2019	20,00	10,34	13,98
2020	11,54	14,29	13,11
2021	13,33	5,00	7,27
mean	11,27	7,48	9,09

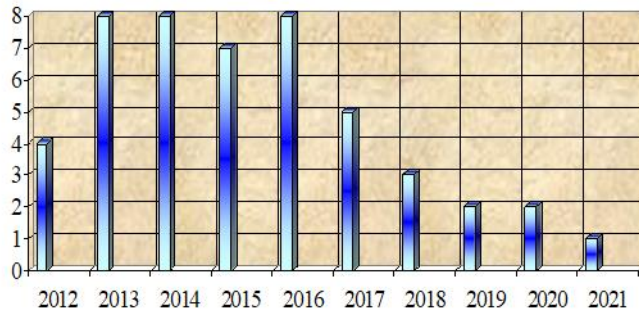
*Table 2. Annual dynamics of the relative share of CRC patients diagnosed by VCS (in %)*

The total relative share of males with synchronous colorectal tumour diagnosed by means of VCS is by 1,63

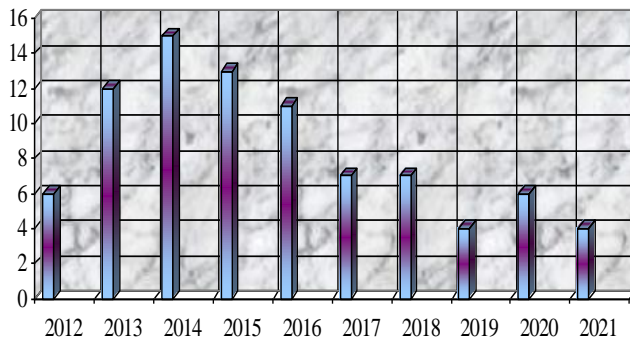
times greater than that of females. The value of the relative share of males with synchronous colorectal tumour diagnosed by means of VCS is greatest in 2015 but smallest in 2012, that of females in 2020 and in 2017, respectively, and that of the total relative share in 2020 and in 2012, respectively. The relative share of males with this colorectal tumour in 2017 is by 3,95 times greater than that of females.

The issue of the differentiation in the synchronous colorectal tumour, whether it deals with a combination of two malignant colorectal diseases, or with the combination of CRC with a colorectal polyp in one and the same patient diagnosed by means of VCS represents an interest, too. The annual dynamics of

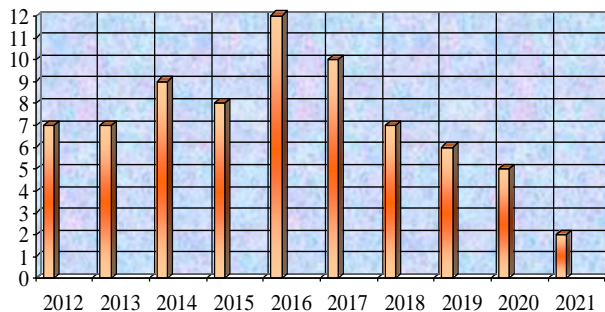
the number of male patients, female patients and all the patients as a whole in whom by means of VCS two malignant colorectal diseases are diagnosed is demonstrated in Fig. 25, Fig. 26, and Fig. 27.



*Fig. 25. Annual dynamics of male patients with synchronous colorectal tumour diagnosed by means of VCS*



*Fig. 26. Annual dynamics of female patients with synchronous colorectal tumour diagnosed by means of VCS*



*Fig. 27. Annual dynamics of all the patients as a whole with synchronous colorectal tumour diagnosed by means of VCS*

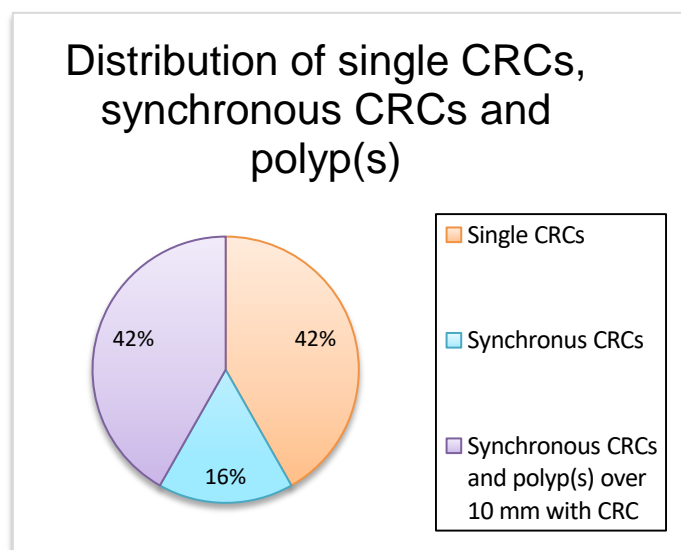
It deals with a total of 26 patients (16,88% of all the patients with CRC), 14 males (17,28% of the male patients with CRC) and 12 females (16,44% of the female patients with CRC).

*Table 3. Relative share of the patients with synchronous colorectal tumour diagnosed by means of VCS (in %)*

<b>Year</b>	<b>males</b>	<b>females</b>	<b>total</b>
<b>2012</b>	3,85	2,02	2,96
<b>2013</b>	7,92	3,92	5,91
<b>2014</b>	9,41	6,14	7,54
<b>2015</b>	9,72	5,41	7,10
<b>2016</b>	6,20	3,31	3,55
<b>2017</b>	5,81	1,47	3,15
<b>2018</b>	4,55	4,00	4,22
<b>2019</b>	5,71	3,45	4,30
<b>2020</b>	7,69	11,43	9,84
<b>2021</b>	6,67	7,50	7,27
<b>mean</b>	6,68	4,10	5,19

With the histological examination, two groups of patients with synchronous neoplasms of the colon and rectum are differentiated: Patients with two synchronous colorectal cancers (26 or 16,88%) and patients with colorectal carcinoma and synchronous polyp(s) of high risk - over 10 mm (66 or 21,48%)

The graphical distribution of single CRCs, synchronous CRCs and polyp(s) over 10 mm with CRC is displayed in Fig. 28.



*Fig. 28. Distribution of single CRCs, synchronous CRCs and polyp(s) over 10 mm with CRC*



In case of colorectal pathology established by means of VCS, a group of 306 patients (37,7%) is formed in whom a total FCS is performed following the preparation by cecum intubation. Among them, 66 patients (8,13%) are confirmed and histologically verified as CRC during this period. A limitation of this analysis is the fact that the patients with large bowel neoplasm already established by means of VCS are included only. A control group is used when comparatively analyzing the results from VCS and FCS. The falsely-positive and the falsely-negative results are identified (Table 4) and specificity and sensitivity of VCS for CRR of 99% and 94%, respectively, are established.

*Table 4. Falsely positive and the falsely negative results of VCS for CRC*

CRC		VCS		
			Positive	Negative
FCS	Total number	306	63	243
			Truely positive	Falsely negative
	Positive	65	61	4
			Falsely positive	Truly negative
	Negative	241	2	239

It should be emphasized that a total of 88 patients with CRC have been omitted during the examination by means of FCS which have been timely diagnosed by means of VCS. All the omitted CRCs are proximally located.

The annual dynamics of the number of these omitted cases during the examination by means of FCS is illustrated in Fig. 29.



*Fig. 29. Annual dynamics of the cases with omitted CRC during the examination by means of FCS*

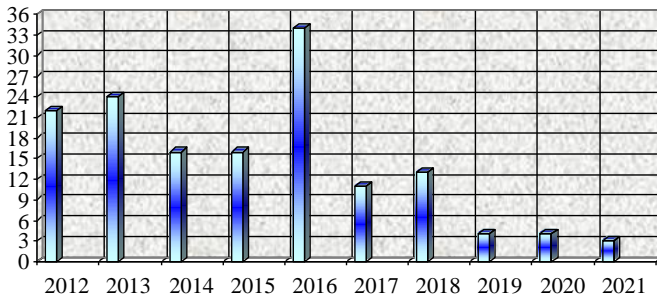
The annual dynamics of the relative share of these cases towards the total number of the patients examined by means of FCS during this ten-year period is demonstrated in Table 5.

Year	%
<b>2012</b>	6,74
<b>2013</b>	9,62
<b>2014</b>	8,42
<b>2015</b>	11,36
<b>2016</b>	13,55
<b>2017</b>	8,41
<b>2018</b>	8,57
<b>2019</b>	17,07
<b>2020</b>	24,24
<b>2021</b>	
<b>total</b>	10,84

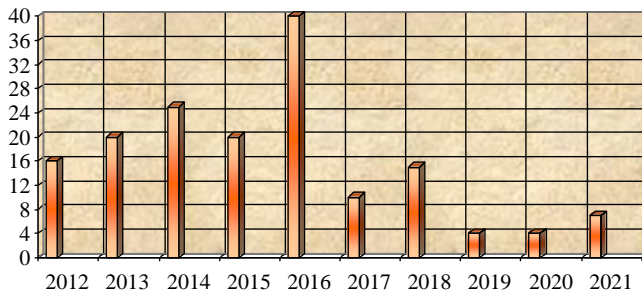
*Table 5. Annual dynamics of the relative share of the cases with omitted CRR towards the total number of the patients examined by means of FCS (in %)*

## 5.2. Diagnostic role of virtual colonoscopy in colorectal polyp patients

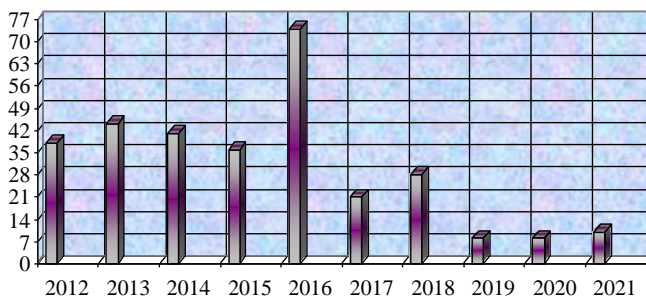
During the ten-year period, virtual colonoscopies are carried out in 1695 patients. Some 308 patients (18,17%) with colorectal polyps are established - 147 males (20,44%) and 161 females (16,50%). The annual dynamics of the number of the male patients, female patients and all the patients as a whole in whom by means of VCS a colorectal polyp is diagnosed is demonstrated in Fig. 30 - Fig. 32.



*Fig. 30. Annual dynamics of male patients with colorectal polyp diagnosed by means of VCS*



*Fig. 31. Annual dynamics of female patients with colorectal polyp diagnosed by means of VCS*



*Fig. 32. Annual dynamics of all the patients patients with colorectal polyp diagnosed by means of VCS*

The total relative share of males with colorectal polyp diagnosed by means of VCS is by 1,24 times greater than that of females. The value of the relative share of males with colorectal polyp diagnosed by means of VCS is greatest in 2016 but smallest in 2019, while the values of the relative of females and the total relative share are in 2016 and in 2019, respectively. The relative share of males with colorectal polyp in 2017 is by 1,74 times greater than that of females.

The annual dynamics of the relative share of the patients with colorectal polyp diagnosed by means of VCS is shown in Table 6.

<b>Year</b>	<b>males</b>	<b>females</b>	<b>total</b>
<b>2012</b>	21,15	16,16	18,72 %
<b>2013</b>	23,76	19,61	21,67 %
<b>2014</b>	18,82	21,93	20,60 %
<b>2015</b>	22,22	18,02	19,67 %
<b>2016</b>	26,36	22,10	23,87 %
<b>2017</b>	12,79	7,35	9,46 %
<b>2018</b>	19,70	15,00	16,87 %
<b>2019</b>	11,43	6,90	8,60 %
<b>2020</b>	15,38	11,43	13,11 %
<b>2021</b>	20,00	17,50	18,18 %
<b>total</b>	20,44	16,50	18,17 %

*Table 6. Annual dynamics of the relative share of the patients with colorectal polyp diagnosed by means of VCS (in %)*

The mean colorectal polyp localization (in cm) in the patients examined by means of VCS is displayed in Table 7.

<b>Year</b>	<b>mean localization in cm</b>
<b>2012</b>	46,8
<b>2013</b>	51,5
<b>2014</b>	39,5
<b>2015</b>	61,4
<b>2016</b>	65,9
<b>2017</b>	67,4
<b>2018</b>	55,56
<b>2019</b>	42,0
<b>2020</b>	72,86
<b>2021</b>	69,4
<b>mean</b>	57,232

*Table 7. Annual dynamics of the mean localization of the colorectal polyp (in cm) during the examination by means of VCS*

The mean distance measured in all the patients as a whole with colorectal polyp varies in broad limits - between 39,5 cm in 2014 and 72,86 cm in 2020. The annual dynamics of the mean size of the colorectal polyp (in mm) in the patients examined by means of VCS can be seen in Table 8.

Year	mean size in mm
2012	11,2
2013	9,9
2014	10,9
2015	7,3
2016	11,4
2017	9,7
2018	11,03
2019	11,6
2020	11,33
2021	6,4
mean	10,486

Table 8. Annual dynamics of the mean size of the colorectal polyp (in mm) during the examination by means of VCS

The polyps established by means of VCS are classified according to the size in three groups:

Polyps  $\leq 5$  mm (n=46; 2,71%)

Polyps between 6 and 9 mm (n=153; 5,54%)

Polyps  $\geq 10$  mm (n=109; 6,43%).

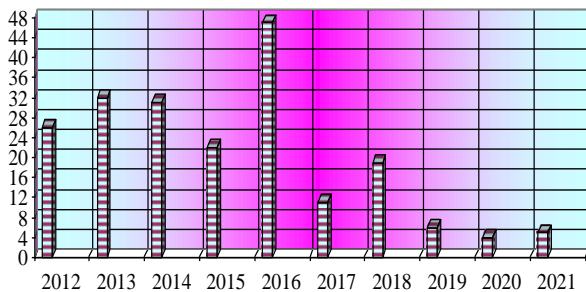


Fig. 33. Annual dynamics of all the patients as a whole with colorectal polyp diagnosed by means of FCS (from the group examined by means of VCS)

The same classification of polyps according to their size is made use of in the diagnosis by means of FCS, too. In FCS, 208 colorectal polyps (25,52%) are detected, 109 in males (52,40%) and 99 in females (47,60%). The relatively small number of FCSs during the last three years is due to the pandemic situation of

COVID-19. The total relative share of males with colorectal polyp diagnosed by means of FCS is by 1,61 times greater than that of females. The value of the relative share of males with colorectal polyp diagnosed by means of FCS is greatest in 2018 but smallest in 2021, that of females in 2019 and in 2020 towards in 2014, respectively, while that of all the patients as a whole in 2014 and in 2020 towards in 2017, respectively. The relative share of males with colorectal polyp in 2018 is by 2,73 greater than that of females. It should be outlined that during the examination of the patients by means of FCS, a total of 66 cases with colorectal polyp are omitted which are timely diagnosed by means of VCS (Fig. 34).

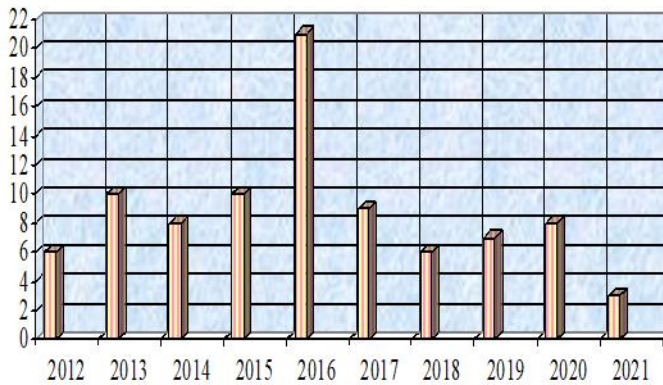


Fig. 34. Annual dynamics of the number of cases with colorectal polyp omitted during the examination by means of FCS towards those by means of VCS

The analysis of the ratio between polyps and CRC detected by means of VCS reveals that 42,85% of CRC patients present with synchronous high-risk polyps sized over 10 mm, too, which is 21,42% of all the polyps established. The patients with single polyps prevail in this group presenting with 61% of the malignant neoplasms established (Fig. 35).

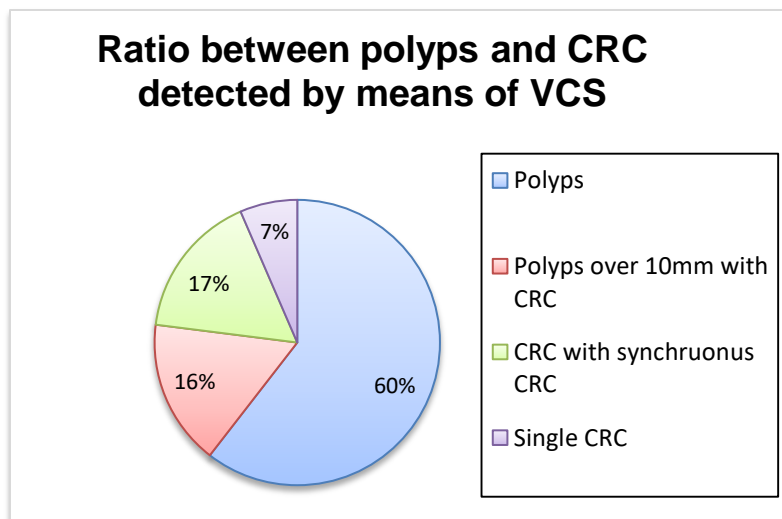


Fig. 35. Ratio between polyps and CRC detected by means of VCS

The falsely-positive and the falsely-negative results in the control group of 308 patients are examined by means of complete FCS and VCS for the determination of VCS sensitivity and specificity for the colorectal polyps (Table 9).

*Table 9. Falsely-positive and falsely-negative results in VCS for polyps*

POLYPS		VCS		
			Positive	Negative
FCS	Total number	306	233	73
			Truely positive	Falsely negative
	Positive	227	219	8
			Falsely positive	Truly negative
	Negative	79	14	65

We establish VCS specificity for polyps of 82% and VCS sensitivity of 96%. By using of error-matrix algorithm we determine a positive prognostic value for polyps of VCS of 93,99% and a negative prognostic one of 89,04%.

Both VCS sensitivity and specificity increase by enlargement of the dimensions of the neoplasms as demonstrated in Table 10. Both VCS sensitivity and specificity for CRC and colorectal polyps are presented in Table 11.

The processing of the results from VCS and FCS concerning polyps from the different groups reveals a statistically significant difference in polyps  $\leq 5$  mm on the account of FCS. By means of optical endoscopy, 8,37% of polyps  $\leq 5$  mm while by means of VCS, 2,71% of them are established ( $p < 0,05$ ) (Table 12).

*Table 10. VCS sensitivity and specificity depending on polyp size*

Polyp size	Sensitivity	Specificity
$\leq 5$ mm	73,0%	94,4%
6 - 9 mm	84,1%	95,6%
$\geq 10$ mm	90,3%	98,5%
total	82,1%	96,0%

*Table 11. VCS sensitivity and specificity for colorectal cancer and colorectal polyps*

Neoplasm type	sensitivity	specificity
Benign neoplasm	82,1%	96,0%
Carcinoma	94,0%	99,0%

*Table 12. Polyps established by means of VCS and FCS*

Polyps	VCS		FCS		p-value
	n=308	%	n=208	%	
≤5 mm	46	2,71%	68	8,37%	<u>p&lt;0,05</u>
6 - 9 mm	153	5,54%	94	11,57%	p>0,05
≥10 mm	109	6,43%	41	5,05%	P>0,05



### 5.3. Diagnostic role of virtual colonoscopy in other large bowel and extracolonic diseases

By means of VCS during the period of examination, among 1695 analyzed patients not only neoplasms of the colon and rectum are established but also three other patients' groups with detected benign extracolonic pathologies (377 patients, 22,24%), malignant extracolonic tumours (104 patients, 6,14%) and other benign large bowel diseases (282 patients,16,64%) are formed.

The most common benign extracolonic diseases diagnosed by means of VCS are shown in Table 13 and as annual dynamics in Fig. 36.

Table 13. Common benign extracolonic diseases in VCS

No	Disease	n	%
1.	Hiatal hernia	96	5,66
2.	Liver hemangioma	46	2,71
3.	Nephrolithiasis	45	2,65
4.	Cholelithiasis	33	1,95
5.	Ventral herniae	24	1,42
6.	Renal cyst	23	1,36
7.	Adrenal adenoma	17	1,00
8.	Gynaecological tumours	14	0,82
9.	Intraabdominal abscesses	9	0,53
10.	Dilated bile ducts with cholelithiasis	8	0,47
11.	Other diseases	70	4,13
	Total	377	22,24

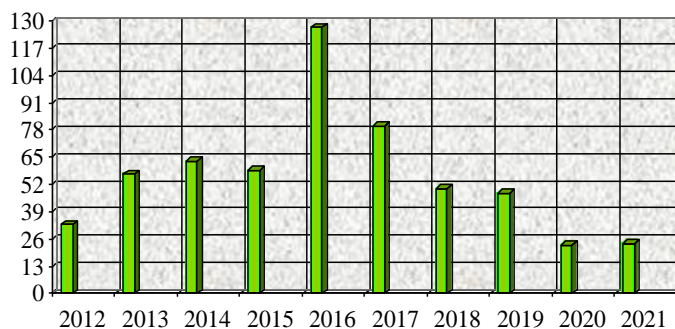


Fig. 36. Patients with benign extracolonic diseases diagnosed by means of VCS

Most common benign extracolonic diseases diagnosed by means of VCS

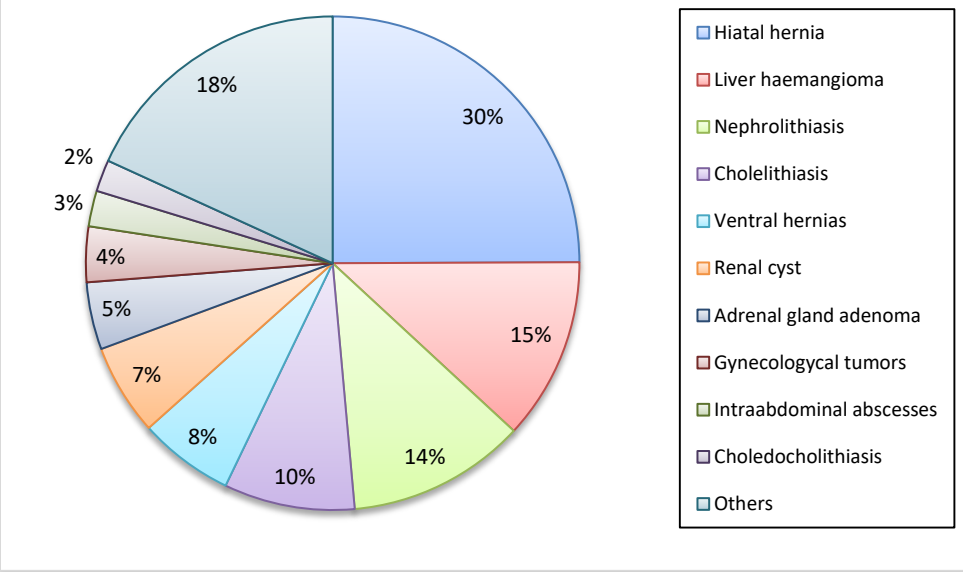


Fig. 37. Most common benign extracolonic diseases diagnosed by means of VCS

Under the heading of ‘other’ (70 patients, 4,13%), some more seldom diseases are included and presented in Table 14. The vascular pathology such as thrombosis of vena cava inferior (v.c.i.), thrombosis of vena portae (v.p.), abdominal aorta aneurysm (4 patients or 0,0023% each), other venous anomalies (5 patients or 0,0029%), sigmoidvaginal fistula (4 patients or 0,0023%), desmoid tumour (one patient or 0,0005%) etc., represent an interest.

Table 14. Rare extracolonic diseases detected by means of VCS

Rare extracolonic diseases	Number of patients	%
Inguinal hernias	6	0,0035%
Venous anomalies	5	0,0029%
Pleural effusions	5	0,0029%
Aneurysm of abdominal aorta (AAAo)	4	0,0023%
Pulmonary hemarthroma	4	0,0023%
Acute cholecystitis	4	0,0023%

Pancreatic pseudocyst	4	0,0023%
Sigmovaginal fistula	4	0,0023%
Thrombosis of v.c.i. And v.p.	4	0,0023%
Gist	3	0,0017%
Meckel's diverticle	3	0,0017%
Liver echinococcus	3	0,0017%
Large colon lipoma	2	0,0011%
Bohdalek's hernia	2	0,0011%
Desmois tumour	1	0,0005%
Chronic dissection of the aaa	1	0,0005%
Femoral neck necrosis	1	0,0005%
Projectile	1	0,0005%
Alien bodies	1	0,0005%
Chronic fractures	1	0,0005%
Traumatic diaphragmatic hernia	1	0,0005%
Femoral hernia	1	0,0005%
Splenic cyst	1	0,0005%

Some 104 patients with malignant extracolonic diseases (6,14%) of the cases examined by means of VCS are established. The most common of these diseases are indicated in Table 15.

The relative share of the patients with malignant extracolonic diseases diagnosed by means of VCS among all the patients examined by means of this method is greatest in 2013 and smallest in 2021 (Fig. 38).

Under the heading of 'other', stomach carcinoma (4 patients, 0,04%), lung carcinoma (3 patients, 0,03%), prostate carcinoma (3 patients, 0,03%), esophageal carcinoma (one patient, 0,01%) and pheochromocytoma (one patient, 0,01%) are included.

The most common malignant extracolonic diseases diagnosed by means of VCS are illustrated in Fig. 39.

Table 15. Common malignant extracolonic diseases detected by means of VCS

No	Disease	n	%
1.	Liver metastases	31	1,83
2.	Gynaecological carcinomas	10	0,59
3.	Pancreatic cancer	9	0,53
4.	Bone metastases	7	0,41
5.	Renal cancer	7	0,41
6.	Pulmonary metastases	6	0,35
7.	Adrenal gland cancer metastases	6	0,35
8.	Peritoneal metastases	6	0,35
9.	Liver cancer	6	0,35
10.	Patients with six other diseases	16	0,94
	Total	104	6,14

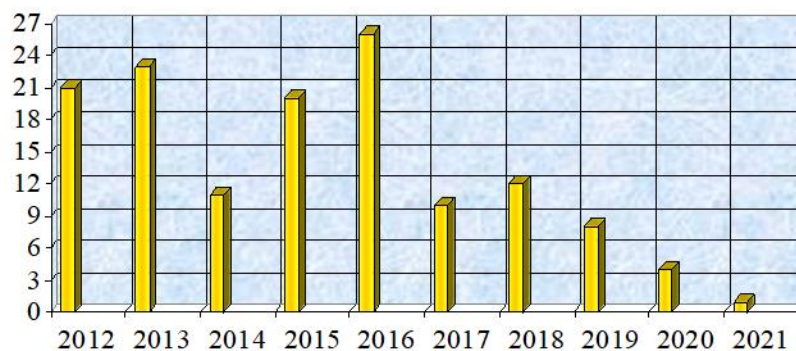
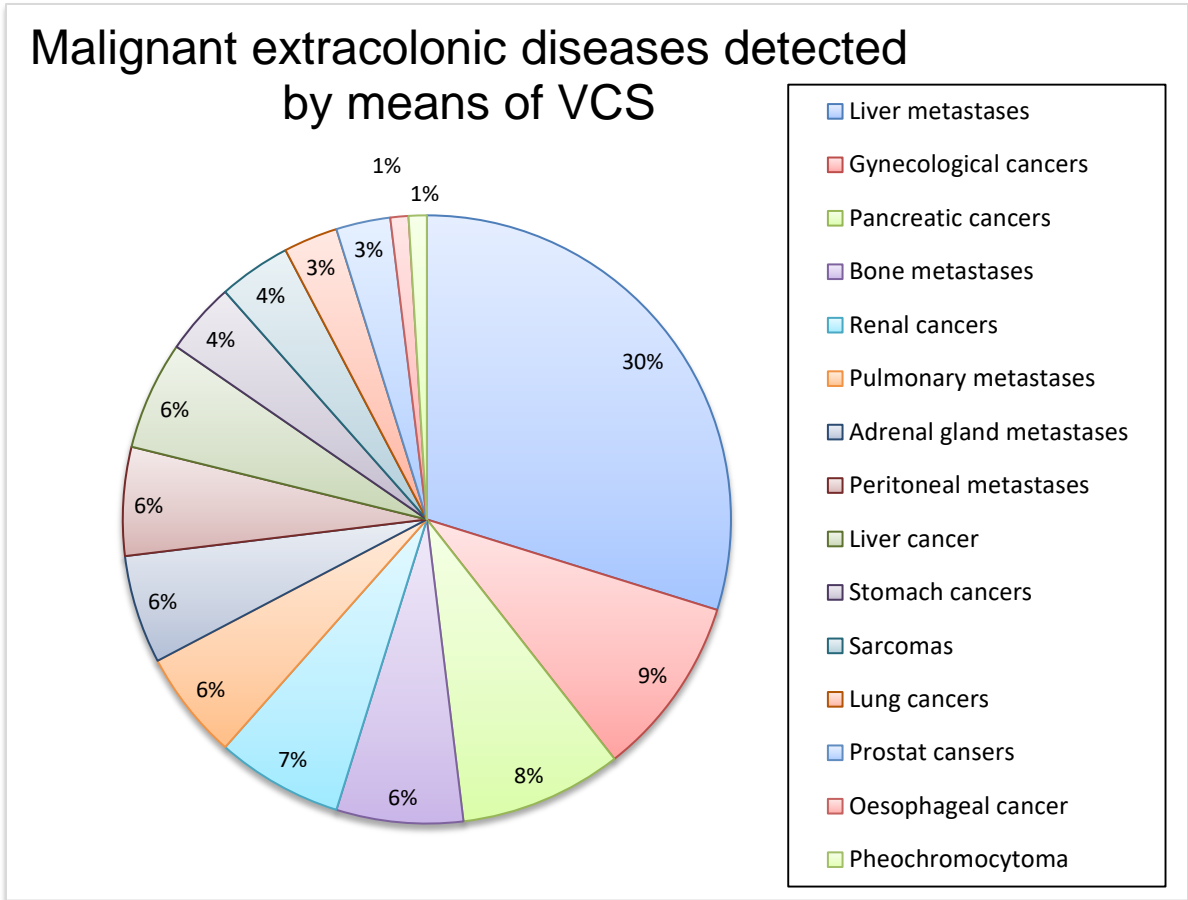


Fig. 38. Annual dynamics of the number of patients with malignant extracolonic diseases diagnosed by means of VCS



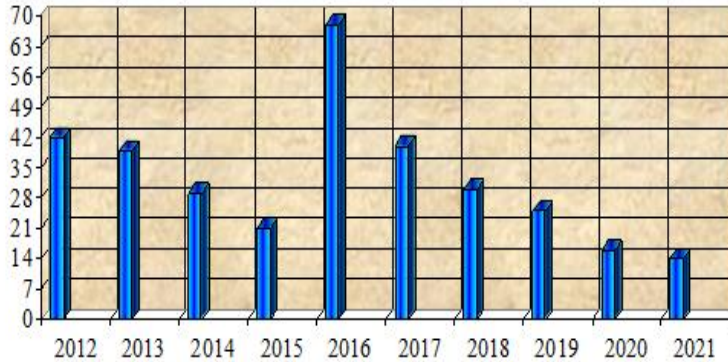
*Fig. 39. Malignant extracolonic diseases detected by means of VCS*

Along with CRC and colorectal polyp, some other benign diseases of the colon and rectum are diagnosed by means of VCS, too. The most common other large bowel diseases are demonstrated in *Table 16*.

*Table 16. Most common other large bowel diseases diagnosed by means of VCS*

No	Disease	n	%
1.	Diverticles	157	9,26
2.	Ileus or stenosis	13	0,77
3.	Anastomosis - anastomositis	12	0,71
4.	Large bowel anomaly	9	0,53
5.	Colitis	9	0,53
6.	Crohn's disease	3	0,18
7.	Other	79	4,66
	Total	282	16,64

The annual dynamics of the number of the patients with other large bowel diseases diagnosed by means of VCS is presented in Fig. 40.

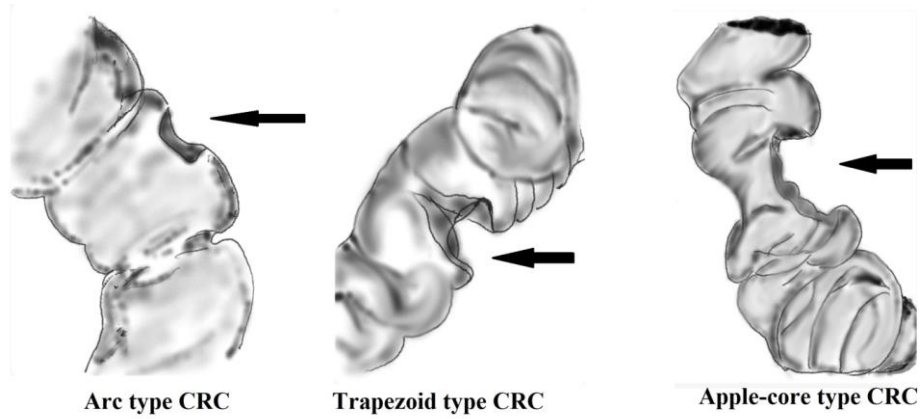


*Fig. 40. Annual dynamics of the number of the patients with other large bowel diseases diagnosed by means of VCS*

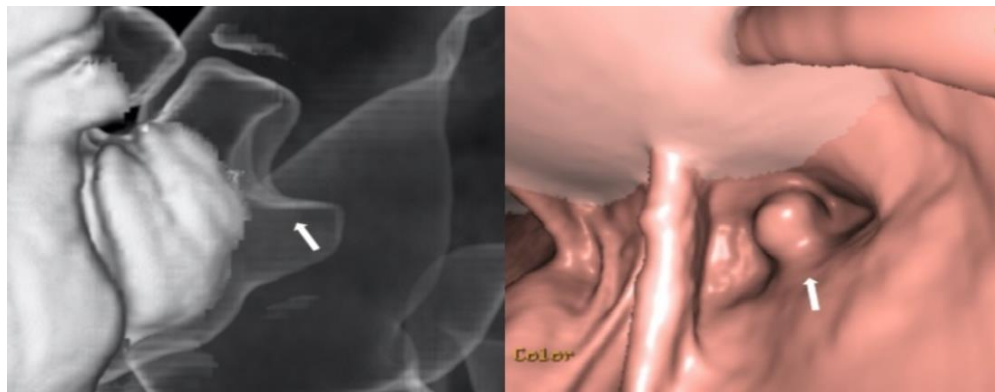
The relative share of the patients with benign extracolonic diseases among all the patients examined by means of VCS is greatest in 2019 and smallest in 2012.

#### **5.4. Diagnostic role of virtual colonoscopy in staging the colorectal cancer patients**

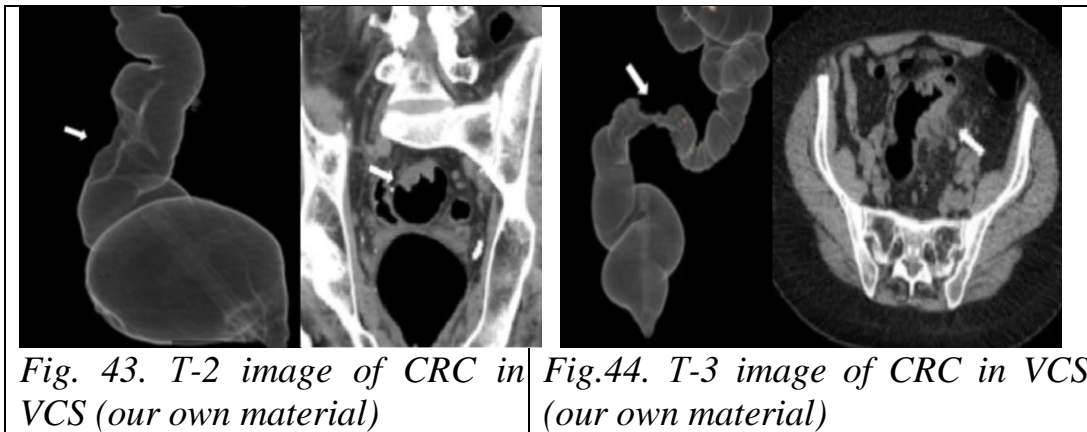
When defining T-stage of the patients with an established malignant process in colon and rectum, the classification according to image data is used. In it, a T-1 is considered the x-ray image of a defect of the wall in the shape of arch (Fig. 41 and Fig. 42), less than 25% of the lumen; a T2 - image of trapezoidal defect of the wall (Fig. 43), occupying 25%-50% of the lumen; a T3 - image of a 'bitted-off apple' of the wall (Fig. 44) with involvement of more than 50% of the lumen or лумена; T-4 is the same image of the 'bitted-off apple', however, with infiltration of the neighbouring structures.



*Fig. 41. T-staging according to image data in VCS*

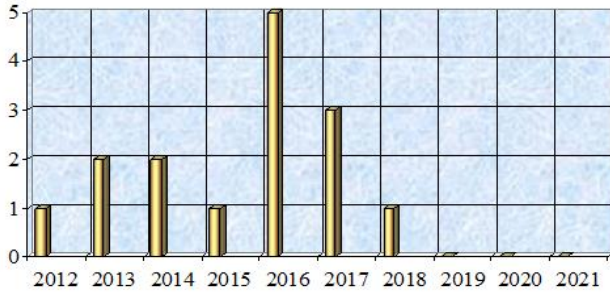


*Fig. 42. T-1 image of CRC in VCS (our own material)*

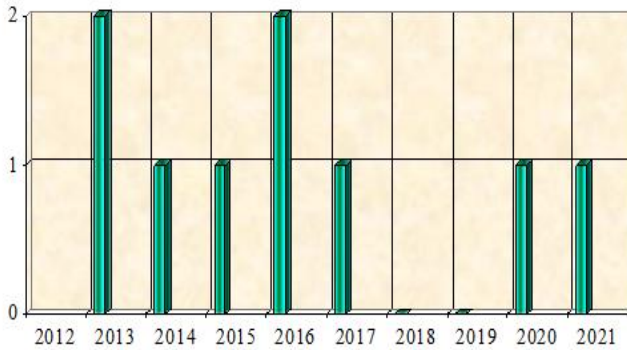


VCSs performed during a ten-year period identify 154 CRC patients classified according to T-stage based on image data. The annual dynamics of all

154 CRC patients diagnosed by means of VCS in T-1, T-2, T-3 and T-4 stage of this disease is illustrated in Fig. 45 through Fig. 48.



*Fig. 45. Annual dynamics of 9 patients with CRC diagnosed by means of VCS at stage T-1 of the disease*

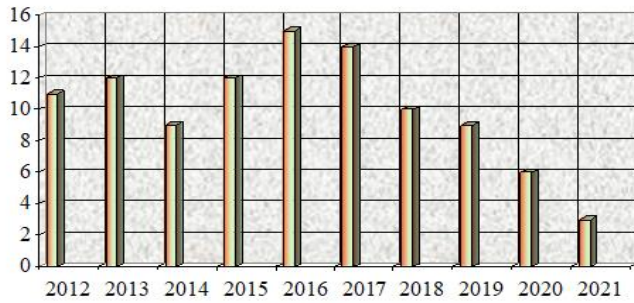


*Fig. 46. Annual dynamics of 29 patients with CRC diagnosed by means of VCS at stage T-2 of the disease*



*Fig. 47. Annual dynamics of 101 patients with CRC diagnosed by means of VCS at stage T-3 of the disease*





*Fig. 48. Annual dynamics of 15 patients with CRC diagnosed by means of VCS at stage T-4 of the disease*

The annual dynamics in % is expressed in Table 17 through Table 20.

Year	%
2012	0
2013	10,53
2014	6,25
2015	5,88
2016	7,14
2017	5,00
2018	0
2019	0
2020	12,50
2021	25,00
total	5,84

*Table 17. Annual dynamics of the relative share of 9 patients with CRC diagnosed by means of VCS at stage T-1 of the disease (in %)*

Year	%
2012	29,41
2013	15,19
2014	25,00
2015	17,65
2016	21,43
2017	10,00
2018	8,33
2019	30,77
2020	12,50
2021	0
total	18,83

*Table 18. Annual dynamics of the relative share of 29 patients with CRC diagnosed by means of VCS at stage T-2 of the disease (in %)*

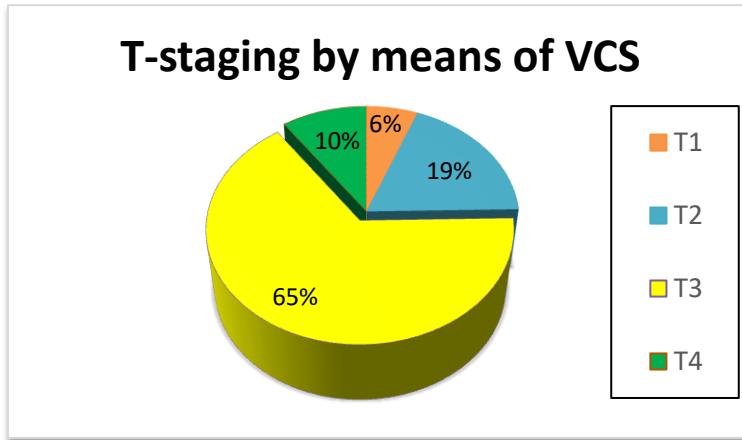
Year	%
2012	64,71
2013	63,16
2014	56,25
2015	70,59
2016	53,57
2017	70,00
2018	83,33
2019	69,23
2020	75,00
2021	75,00
total	65,59

*Table 19. Annual dynamics of the relative share of 101 patients with CRC diagnosed by means of VCS at stage T-3 of the disease (in %)*

Year	%
2012	64,71
2013	63,16
2014	56,25
2015	70,59
2016	53,57
2017	70,00
2018	83,33
2019	69,23
2020	75,00
2021	75,00
total	65,59

*Table 20. Annual dynamics of the relative share of 15 patients with CRC diagnosed by means of VCS at stage T-4 of the disease (in %)*

The graphical distribution of T-stage of the disease in the examined group is presented in Fig. 49. We establish that 6% of the patients are in T-1 stage, 19% - in T-2 stage, 65% - in T-3 stage and 10% - in T-4 stage.



*Fig. 49. T-staging by means of VCS*

The gender distribution reveals a slight predomination of females with CRC (Table 21 and Fig. 50).

*Table 21. CRC distribution according to gender and T-stage by means of VCS*

Stage	Males	Females	Total	
			n	%
T1	4	5	9	5,84
T2	11	18	29	18,83
T3	47	54	101	65,59
T4	12	3	15	9,74
total	74	80	154	100,00%

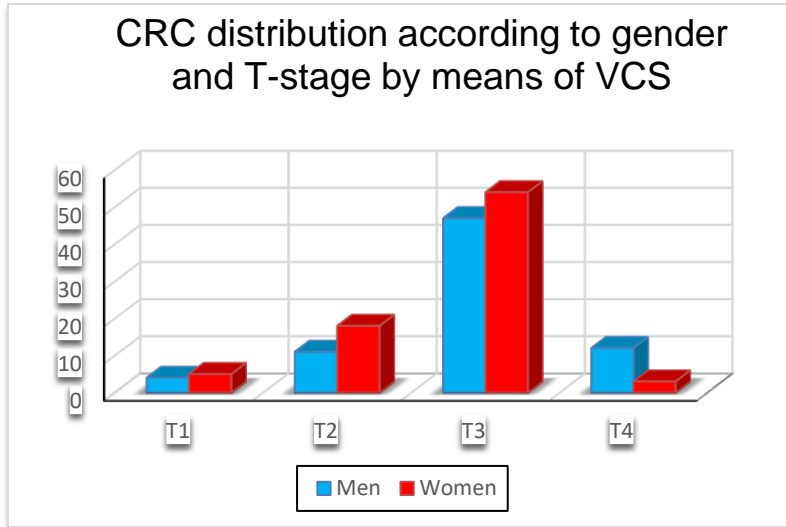


Fig. 50. CRC distribution according to gender and T-stage by means of VCS

Table 22. Comparison between VCS and CT for T-stage determination

T-stage	VCS		CT		p-value
	n=154	%	n=154	%	
T1	9	5,84%	4	2,60%	<u>p&lt;0,05</u>
T2	29	18,83%	21	13,64%	<u>p&lt;0,05</u>
T3	101	65,58%	109	70,78%	p>0,05
T4	15	9,74%	20	12,99%	p>0,05

The considerably greater number and relative share of the patients in T-3 stage of CRC strikes, i.e. by 3,48 times when compared with those in T-2 stage and even by 11,23 times in comparison with those in T-1 stage.

Out of the established 154 CRC patients, 138 ones are operated on and histologically examined. The pathoanatomical results obtained for T-stage are juxtaposed to the preliminary images for T-stage from VCS. A statistically significant difference is established in terms of T-1 stage only. In the rest T-stages (T-2, T-3, and T-4), there is no significant difference when comparing both examinations.

In all the patients with established CRC, along with T-stage, N-stage in the locoregional lymph basin as well as the possible distant lesions for M-stage in the zones scanned by means of VCS are specified.

The comparison between VCS and the histological result when defining the T-stage is demonstrated in Table 23.

Table 23. Comparison between VCS and the histological result when defining the T-stage

T-stage	VCS		Pathoanatomical examination		p-value
	n=136	%	n=136	%	
T1	8	5,88%	4	2,94%	p<0,05
T2	26	19,11%	31	22,79%	p>0,05
T3	92	67,64%	90	66,17%	p>0,05
T4	10	7,35%	11	8,08%	p>0,05

### 5.5. Diagnostic role of virtual colonoscopy in the choice of a surgical method

The determination of the tumour localization is the basis for the planning of the operative method. By means of VCS we establish 154 CRC patients in whom distal localizations prevail. The anatomical distribution of CRC is illustrated in Fig. 51.

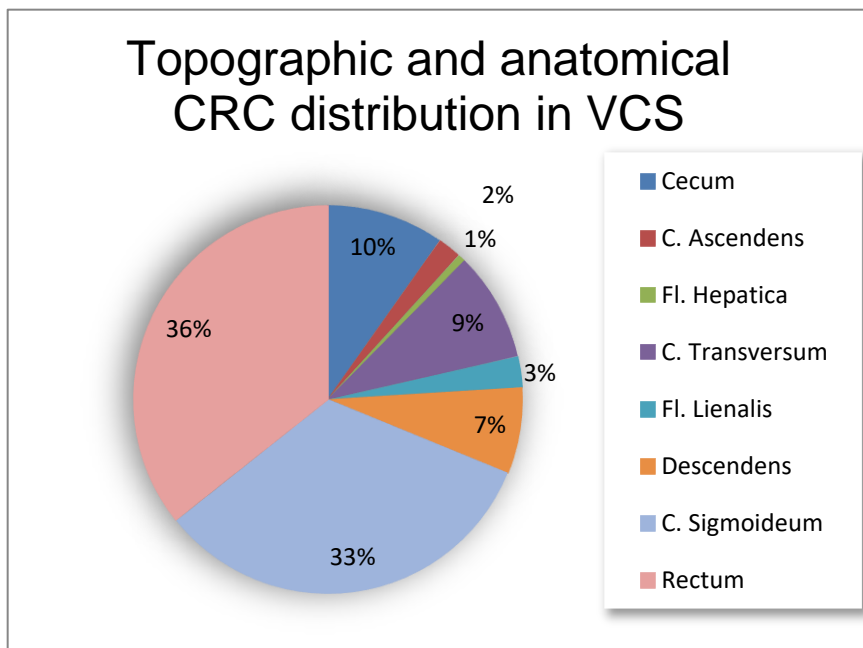


Fig. 51. Anatomical distribution of CRC in VCS

In VCS, 69% of CRCs are established in rectum and sigmoid colon.

The mean distance of CRC from the anal edge analyzed amounts to 51,19 cm. These 26 synchronous carcinomas representing 16,88% of all the CRCs are located proximally from this mean distance.

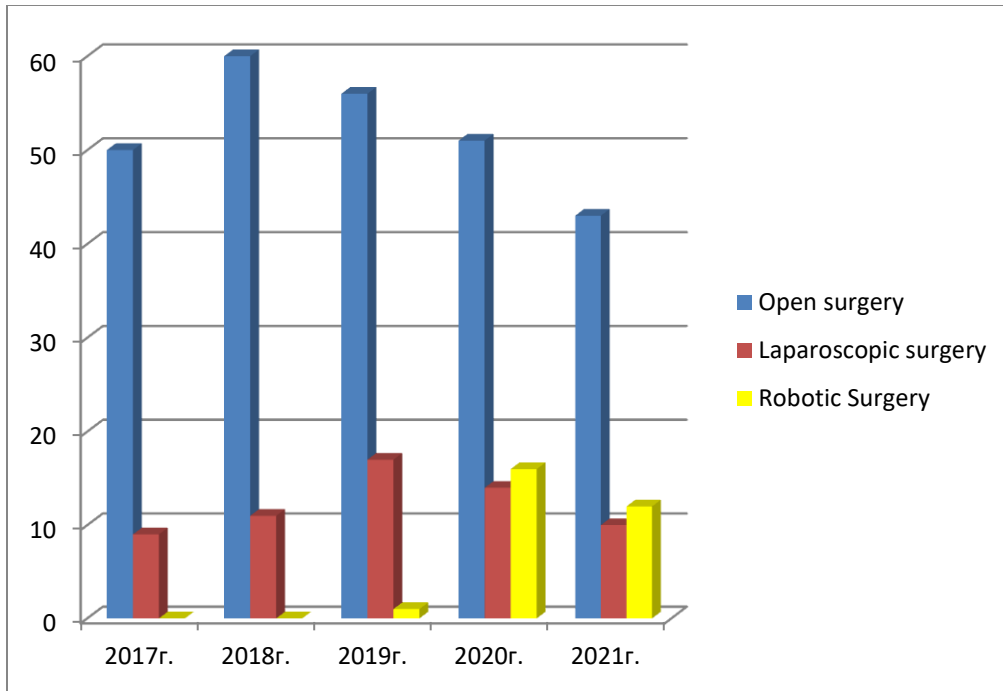
The comparative analysis of CRC localization between VCS and FCS reveals statistically significant differences in CRC right localizations as 88 of them (57,14%) are not detected by means of FCS (Table 24).

Table 24. CRC localization in VCS and FCS

Localization	VCS		FCS		p-value
	n= 154	%	n= 66	%	
Cecum	15	9,74%	2	3,03%	<u>p&lt;0,05</u>
C. Ascendens	3	1,95%	1	1,52%	p>0,05
Fl. Hepatica	1	0,65%	0	0,00%	<u>p&lt;0,05</u>
C. Transversum	14	9,09%	6	9,09%	p>0,05
Fl. Lienalis	4	2,60%	0	0,00%	p>0,05
C. Descendens	11	7,14%	8	12,12%	p>0,05
Sigmoid colon	51	33,12%	22	33,33%	p>0,05
Rectum	55	35,71%	27	40,91%	p>0,05

The patients operated on during the period between January 1, 2012 and December 31, 2020 on the occasion of colorectal cancer are 715 as conventional operative interventions are 603 (84,33%) but minimally invasive ones are 112 (15,67%). The minimally invasive operations include laparoscopic operations in 83 patients (11,60%) and robot-assisted surgery in 29 patients (4,06%). During the last five years, a tendency towards an increase of the number of the minimally invasive interventions on the account of the conventional ones is observed. During the last three years, the number of the robot-assisted operations increases, too.

The annual dynamics of the operative interventions in 2017-2021 is demonstrated in Fig. 52.



*Fig. 52 Operative interventions performed during the period between 2017 and 2021*

Some 136 CRC patients of the 715 ones operated on (19,02%) are preoperatively staged by means of VCS while the rest 579 ones (80,98%) are diagnosed without VCS. Thus two patients' groups are created - group-1 with VCS and group-2 without VCS. We divide each group into conventionally operated (CO) and minimally invasively operated (MI) patients. The distribution obtained is the following (Table 25):

Table 25. Patients's distribution according to type of operation and VCS usage

Group-1 with VCS		Group-2 without VCS	
CO	MI	CO	MIO
115 (16,08%)	21 (2,93%)	488 (68,25%)	91 (12,73%)

The intraoperative results in terms of tumour localization and necessity of intraoperative optical endoscopy for marking CRC localization during the minimally invasive operations because of absent tactile sensation are analyzed. A coincidence of tumour localization and the operative plan accomplished in group-1 with VCS is established presenting with a statistically significant difference with group-2 without VCS (Table 26).

Table 26. Minimally invasively (MI) operated patients with and without VCS

	Group-1 with VCS		Group-2 without VCS)		p-value
	n=21	%	n=91	%	
Coincidence of operative plan	20	95,23%	78	85,71%	<u>p&lt;0,05</u>
Non-coincidence of operative plan	1	4,76%	9	14,29%	<u>p&lt;0,05</u>
Intraoperative FCS	0	0,00%	3	3,29%	<u>p&lt;0,05</u>

Some 26 synchronous carcinomas (16,88%) within 154 primary ones are established. This leads to change of the operative strategy through resection volume enlargement. Besides 109 colorectal polyps over 10 mm (35,38%), high-risk precanceroses, are established which require radicality concerning them, too. Of them, 66 (21,42%) are associated with a primary CRC. The changed operative programme is demonstrated in Table 27. The primary and synchronous carcinomas are graphically shown in Table 28. There is prevalence of the primary carcinomas of left colon-rectum with synchronous of left colon synchronous with colon transversum and synchronous of right colon as they are 22 (88%) of all the synchronous carcinomas. The rest 12% are distributed among a primary of right colon with synchronous of right colon and synchronous of colon transversum. In



the group examined, no primary CRC of colon transversum with synchronous of colon transversum is detected at all (Table 28).

Table 27. Extended operative intervention according to the primary and synchronous carcinoma

Primary crc in vcs		Cecum	C. Ascendens	Fl. Hepatica	C. Transversum	Fl. Lienalis	C. Descendens	Sigmoid colon	Rectum
Cecum	15	0	1	0	0	0	1	1	3
C. Ascendens	3	0	0	0	1	0	0	2	0
Fl. Hepatica	1	0	0	0	1	0	0	0	
C. Transversum	14	0	0	0	0	0	1	3	1
Fl. Lienalis	4	0	0	0	0	0	0	0	
C. Descendens	11	0	0	0	0	0	0	2	
Sigmoid colon	51	0	0	0	0	0	0	0	4
Rectum	55	0	0	0	0	2	3	0	0

Table 28. Primary and synchronous CRC in VCS

	Primary	Synchronous	Operation
1	Rectum	Fl. Lienalis	LHC+ ARR
2	Sigmoid colcon	C. Ascendens	RHC + SR
3	C. transversum	Fl. Hepatica	Extended RHC
4	Rectum	Cecum	RHC + Hartmann rectum resection
5	Sigmoid colon	C. Transversum	SR + TR
6	Rectum	Sigmoid c.	ARR + SR
7	Rectum	C. transversum	Milles rectum extirpation + RHC
8	Sigmoid colon	C. Ascendens	Subtotal colectomy

Legend: RHC - right hemicolectomy, TR - transersum colon resection, LHC - left hemicolectomy, SR - sigmoid colon resection, ARR - anterior rectum resection

Primary colorectal carcinomas in the examined group are associated with synchronous polyps, too, as 66 of them (21,42%) are clinically significant and

sized over 10 mm. The CRCs with synchronous polyps of left colon and right colon transversum prevail (in 56% of the cases) (Fig. 53).

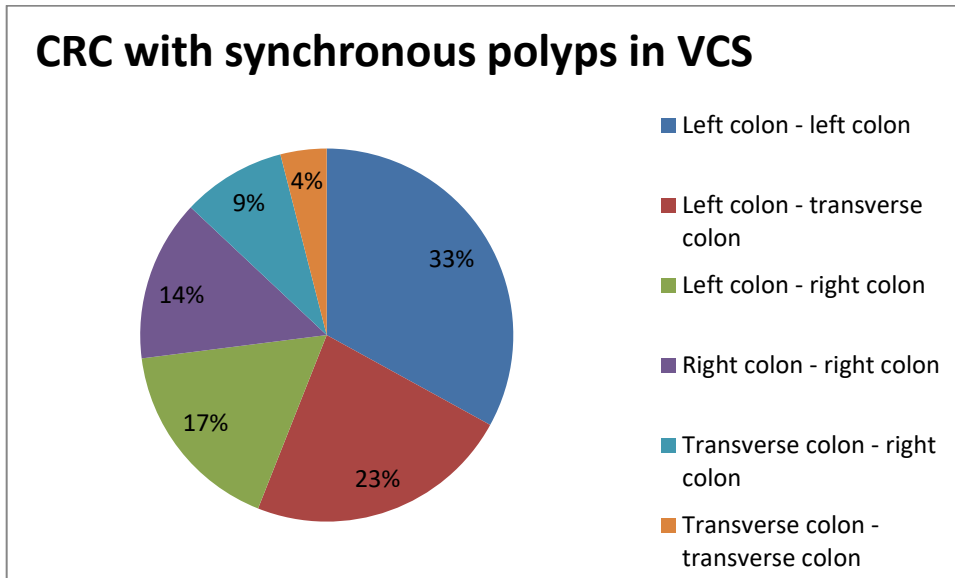


Fig. 53. A primary CRC with synchronous polyps sized over 10 mm

The relative shares of the primary and synchronous carcinomas are illustrated in Fig. 54.

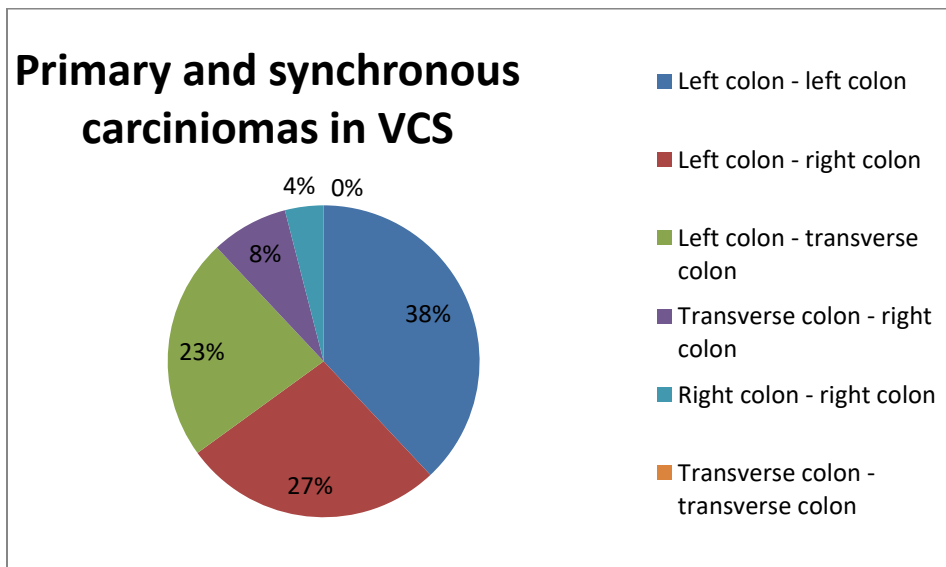
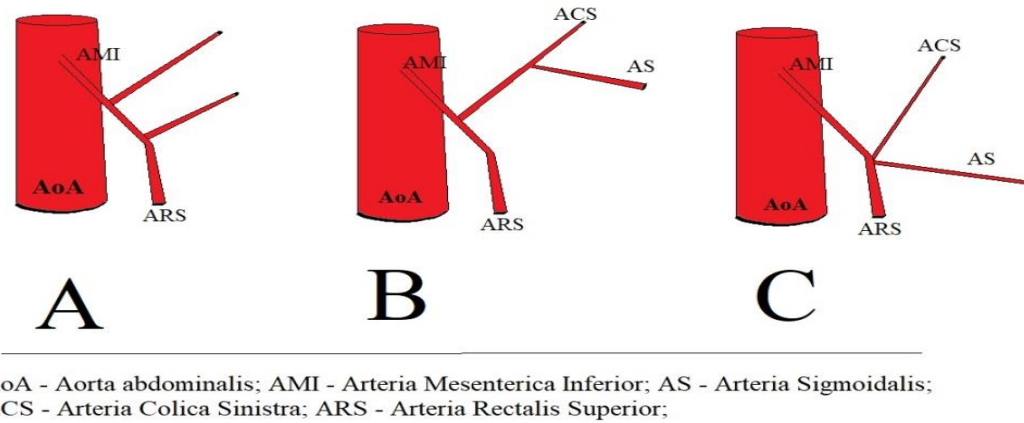
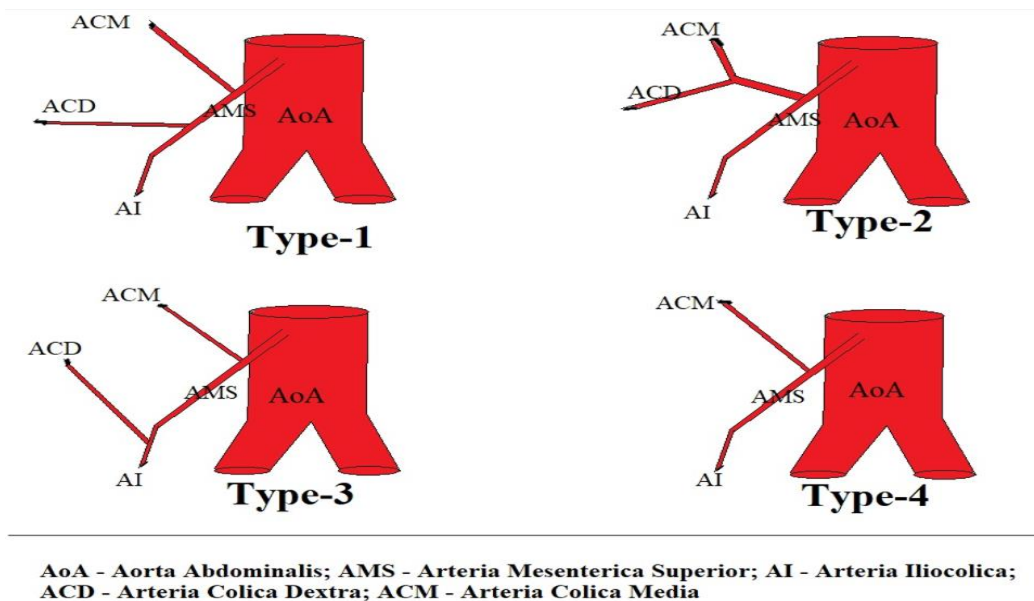


Fig.54. Primary and synchronous carcinomas in VCS

The preoperative planning of the 154 carcinomas detected by means of 1695 VCSs also includes a detailed analysis of the vascular anatomy of arteria and vena mesenterica inferior with their branches in left CRC localization (Fig. 55) as well as of arteria and vena mesenterica superior with their branches in right localizations of the neoplastic process (Fig. 56).



*Fig.55. Variations of arteria mesenterica inferior branches*



*Fig.56. Variations of arteria mesenterica superior branches*

In all 21 patients (2,93%) from group-1 MI, the vascular anatomy is analyzed by means of VCS with reconstruction of the variations, too. The control group-2 MI without VCS includes 91 patients (12,73%). During this analysis of the vascular anatomy, we establish that arteria colica dextra (ACD) is a separate branch in 6 patients (20,69%) operated on with RHC while ACD as a branch of arteria ileocolica in three patients (15,79%). No patients with ACD variation of type-2 and type-4 are established in the group selected. In LHC, C-type of separation of arteria colica sinistra, arteria sigmoidalis and arteria rectalis superior is detected in 16 patients (71,42%). There is no B-type in the group examined while A-type occurs in the rest 5 patients (23,80%).

All the patients are operated on by using of minimally invasive methods, including robot-assited ones in 11 of them from group-1 MI and four from group-2 MI. The parameters analyzed and the results obtained are displayed in Table 29.

*Table 29. Analysis of parameters in patients operated on with MI who are with and without VCS*

Analyzed parameters	Group-1 MI with VCS	Group-2 MI without VCS	p - value
	n=21 (2,93%)	n=91 (12,73%)	
Operative time	205 min.	237 min.	p>0,05
Vascular dissection	63 min.	95 min.	p<0,05
Lymph nodes	19	11	p>0,05
Vascular lesion	1 (4,76%)	12 (13,18%)	p<0,05
Conversion	1 (4,76%)	9 (9,90%)	p<0,05
Insufficiency	0 (0,00%)	6 (6,59%)	p<0,05

The hospital stay is comparable in both groups and it is within 11±6 days for group-1 MI and 10±6 days for group-2 MI. There is no perioperative mortality.

## **6. DISCUSSION**

### **6.1. Diagnostic value of virtual colonoscopy in colorectal cancer patients**

When analyzing the world literature in terms of the role of virtual colonoscopy in CRC, we should obligatorily agree with leading authors about the necessity of multimodality in the treatment of this significant disease worldwide. Optical colonoscopy remains a golden standard in CRC diagnosis as well as in histological verification. In an investigation by means of colonoscopy of 1219 persons with a preliminary positive finding during CRC screening in China, the following five most-important risk factors are identified: chronic constipation (in 25,9%), chematochezia (in 23,5%), familial history of colorectal cancer in first-line relatives (in 22,1%), chronic diarrhea (in 21,8%), and history of colorectal polyps (in 16,6% of the cases) (Li et al. 2022). Approximately 14,2% of the participants in the inquiry investigation who are with a preliminary positive finding during CRC screening report about three and more risk factors for the disease.

The preciseness of the preoperative conventional colonoscopy and computed tomography is juxtaposed to the findings from the operation within a prospective multicenter investigation on behalf of the Italian Society of Colorectal Surgery in a total of 745 patients from 23 centres during the period between January 1, 2019 and December 31, 2019 (V. Rai, N. Mishra, 2018). There is no significant difference between both imaging methods in terms of the correctly localized large bowel lesions (in 510 versus 499 of 661 lesions;  $p=0,518$ ) and of the lesions visible by means of computed tomography (in 331 versus 340 of 427 lesions;  $p=0,505$ ). The juxtaposition of both methods based on the intraoperative localization of the lesions in the descendent colon demonstrates statistically significantly poorer results when diagnosing by means of colonoscopy than of computed tomography (in 17 out of 32 lesions;  $p=0,031$ ).

The analysis of more than 200 000 colonoscopic images of 1572 colorectal polyps demonstrates sensitivity of a new integrated computed system concerning the improved recognition of the lesions of 92,9%, specificity of 90,6%, and

preciseness of 91,7%, while concerning the improved optical diagnosis - of 85,0%, 79,4% and 83,6%, respectively (Weigt et al. 2022).

By means of colonoscopy, colorectal polyp incidence rate is detected in 65,2% among 1024 males and in 48,5% among 472 females aged between 65 and 80 years (Zhang et al. 2021). The odds ratio towards obesity is 1,151 (between 1,010 and 2,291 at confidence interval of 95%) in males and 1,178 (between 1,015 and 2,612 at confidence interval of 95%) in females.

Colorectal polyps are diagnosed by means of colonoscopy in 12,95% out of 1027 consecutive patients at a mean age of 45 years and in 9,73% out of 735 patients at an age of more than 40 years in a tertiary medical centre in Nepal (Koirala et al. 2021). The polyps are most commonly localized in the rectum - in 46,62% of the cases. The incidence rate of adenomatous polyps is 43,61%, of hyperplastic - 11,28%, of inflammatory - 22,56% and of juvenile ones - 18,05%.

The results from a retrospective cohort study by means of colonoscopy in a total of 4475 young individuals (aged below 50 years) who are at a mean age of  $40,2 \pm 8,0$  years during the period between 2014 and 2019 demonstrate a total frequency of the diagnosed colorectal polyps of 22% (Pang et al. 2022). The adenomatous polyps prevail (in 58,9% of the cases).

In the investigation of 399 patients, 213 males and 186 females at a mean age of 73 years (between 32,4 and 82,1 years) with primary CRC during the period between July 2014 and June 2017 by means of colonoscopy for seven up to 36 months seven patients (1,75% of the cases) are diagnosed in whom it deals with an omitted CRC after the initial colonoscopic examination (Laurent et al. 2021). The mean interval between the falsely-negative initial colonoscopy and the definitive diagnostic colonoscopy is 18,7 months (between 9,1 and 34,9 months). Two omitted cases each are localized in colon ascendens and colon sigmoideum and one case each - in rectum, colon transversum, and colon descendens.

The size of rectum cancer and the distance between anal edge and the lower or upper tumour border are laterally measured by means of computed tomographic colonography and enema with double-contrast barium sulphate in 147 patients at an early or advanced stage of the disease (Murai et al. 2022). All the lesions at these stages of rectum cancer are visualized by means of the enema with barium sulphate. Because of the presence of a fluid level formation, three lesions (7,8%) among the cases with an early stage and eight lesions (7,3%) among those at an advanced state of the disease localized on the anterior wall closely to the anal canal

are not detected by means of computed tomographic colonography. The values of the tumour size measured by using of both methods are similar in both patients' groups. The distance between the upper margin of the anal canal and the tumour is longer when making use of barium sulphate enema, particularly in the patients at an early stage of the disease. The differences in terms of the distance between the anal canal and the tumour are statistically significantly greater in the patients at the early than in those at the advanced stage of the disease ( $p=0,0024$ ) (Murai et al. 2022).

A 70-year old patient with moderately differentiated adenocarcinoma in the upper part of the rectum is reported in whom optical colonoscopy and abdominal computed tomography are preoperatively performed (Zhang et al. 2021). During the colonoscopy, a distance between the adenocarcinoma at IVA TNM stage and the anal edge of 14 cm and a tumour size of 2,5 cm×1,5 cm×1 cm are established, while during the computed tomography, a thickened wall in the upper part of the rectum and a dim perirectal adipose tissue suggesting the presence of tumour infiltration is done. A successful transumbilical laparoscopy with one-port robot-assisted total mesorectal excision and with operation duration of 165 min and blood loss of 20 mL only is accomplished.

In the present study during a ten-year period from January 1, 2012 to December 31, 2020, 1695 patients are examined by means of VCS. They are 719 males (42,42%) and 976 females (57,58%). Of them, 812 patients (47,90%) are examined by means of FCS. In the FCS group, total optical colonoscopies with cecum tubing are performed in 306 patients (18,05%) and analyzed as a control group. Most commonly, male and female patients as well as all the patients as whole at the age group between 61 years and 70 years are examined by means of VCS (267, 197, and 464 patients, respectively). Next follow the patients at the age group between 71 years and 80 years (263, 153, and 416 patients, respectively) and those at the age group between 51 years and 60 years (199, 166, and 365 patients, respectively). The analysis of the annual dynamics of the number and relative share of the patients examined by means of VCS demonstrates different values during the single years. They are greatest in 2016 (a total of 310 patients or 18,29%) but smallest in 2021 (a total of 55 patients or 3,24% of the cases). During the examined period, a total of 154 patients (9,09%) are diagnosed with CRC by means of VCS - 81 males (4,78%) and 73 females (4,30%). The relative share of the males with CRC diagnosed by means of VCS is by 1,51 times greater than that of the females.

All the patients with established CRC are analyzed according to T-stage, mean distance of CRC from the anal edge, patients with a single CRC and patients with synchronous neoplasms.

The main CRC characteristics include tumour growth, invasion and dissemination as manifested by TNM staging. The virtual colonoscopy has an enormous potential in this staging as outlined by Kim et al. (2022), too, that disease-free survival is statistically significantly longer in the patients with pT3 stage than in those with pT4 stage (88,6% versus 68,6%;  $p < 0,001$ ). A preoperative computed tomographic scanning is performed in 216 colon cancer patients at T4 clinical stage during the period between January 2015 and December 2015 in South Korea (Kim et al. 2022). A pathological pT3 stage is diagnosed in 114 while a pathological pT4 stage is done in the rest 102 patients. Total survival is statistically significantly longer in the patients with pT3 stage than in those with pT4 stage, too (91,2% versus 76,5%;  $p = 0,002$ ). Perineural invasion and tumour invasion are identified as preoperative risk factors predisposing to pT4 staging ( $p = 0,044$  and  $p = 0,001$ , respectively). Pedrazzini et al. (2022) establish that elective laparoscopic surgery for pT4 CRC does not increase the risk of metachronous peritoneal metastases following radical operative interventions. Long-term results after laparoscopy are comparable with conventional open resections (Pedrazzani et al. 2022). Matsuoka et al. (2018) follow-up by means of VCS the CRC excessive growth for 16 months. There is change of VCS finding from normal to invasive lympho-metastatic CRC during this short period.

We stage CRR according to T-criteria in all the 154 patients, 81 males and 73 females, diagnosed by means of VCS. The greatest number and relative share of the cases in T3 stage of this malignant disease are registered - 101 patients or 65,59% of the cases. Next follow the number and relative share of the cases in T2 stage - with 29 patients (18,83%), in T4 stage - with 15 patients (9,74%) and in T1 stage - with nine patients (5,84% of the cases). The number and relative share of the patients in T3 stage of CRC are considerably greater - by 3,48 times in comparison with those in T2 stage and even by 11,23 times in comparison with those in T1 stage. With a greatest relative share (of 25,00%) are the patients in T1 stage in 2021; with a share of 30,77% are those in T2 stage in 2019; with a share of 83,33% are those in T3 stage in 2018, and with a share of 17,86% are those in T4 stage of the disease in 2016. Females prevail over males among the patients in T2 (18 versus 11), in T3 (54 versus 47) and in T1 stage of the disease (five versus



four). On the other hand, males are by four times more (12 versus three) in T4 stage of the disease. Among the patients examined by means of FCS, 66 CRCs (8,12%) are established within the group examined by VCS as the greatest number and relative share of the cases in T3 stage of this malignant disease are registered, too, 51 patients or 77,27% of the cases. Next follow the number and relative share of the cases in T2 stage - with nine patients (13,64%) and in T1 stage - with five patients (7,58% of the cases). The only female patient with CRC in T4 stage of the disease is diagnosed by means of FCS in the examined group in 2017 (in 1,51% of all the cases). The number and relative share of the patients in T3 stage of CRC are considerably greater - by 5,66 times in comparison with those in T2 and even by 10,19 times in comparison with those in T1 stage. We establish 65,59% of CRC (101 patients) in T3 stage, 18,83% (29 patients) in T2 stage, 9,74% (25 patients) in T4 stage and 5,84% (9 patients) in T1 stage of the disease. Males prevail over females in T4 stage only (with 7,79% versus 1,94%). In the rest stages, T1, T2, and T3, females are more than males with 3,24%, 11,68%, and 35,06%, respectively.

The CT 2-D images from VCS in all the patients with CRC are analyzed. A comparison in terms of the extent of discerning of T stage in both examinations is made. We establish 9 patients (4,84%) in T1 stage and 29 patients (18,83%) in T2 stage when using VCS which are considerably less when using CT in these two stages - four patients (2,69%) and 21 patients (13,64%), respectively, as the difference is statistically significant ( $p < 0,05$ ). The results are comparable when T3 and T4 stages are concerned. Postoperatively, 136 CRC patients (88,31%) are histologically verified and analyzed according to T stage of the disease. A difference in terms of T1 stage by a 50% higher diagnostic value of VCS is established. Pathoanatomically, four patients (2,94%) in T1 stage are confirmed out of the eight patients (5,88%) established by VCS. The analysis by *t*-test of Student-Fisher indicates a statistically significant difference ( $p < 0,022$ ). In the rest T2, T3, and T4 stages, there is difference between VCS and the pathoanatomical result, however, without any statistical significance ( $p > 0,05$ ).

In order to determine the specificity and sensitivity of VCS in terms of CRC in our investigation, this method is juxtaposed to FCS in a group of 306 patients (37,68%) providing a complete inspection during the optical endoscopy and with established colorectal neoplasm. By means of VCS in this highly selected group, 63 CRCs (20,59%) are established while the rest 243 patients (79,41%) are with polyps over 5 mm in size. Among the control FCSs in this group, 65 CRCs

(21,24%) and 241 polyps over 5 mm in size are confirmed. By means of error-matrix-test, four results (1,31%) are defined as falsely-negative and two results (0,65%) as falsely-positive. Based on the results obtained, VCS specificity and sensitivity for CRC are determined as specificity is 99% and sensitivity is 94%. The detailed analysis establishes a positive predictive value of VCS for CRC of 96,8% and a negative predictive value of 98,3%.

The topographic anatomical CRC distribution in the examined group does not reveal any significant differences between both sexes. Rectum and sigmoid colon carcinomas dominate with 55 patients (35,71%) and 51 patients (33,12%), respectively, followed by the carcinomas of cecum, colon transvesum, and colon descendens with 15 patients (9,74%), 14 patients (9,09%), and 11 patients (7,14%), respectively. The rest carcinomas (5,19%) are those of the left and right flexura as well as of colon ascendens, with four patients (2,60%), one patient (0,65%), and three patients (1,95%), respectively.

The mean distance from the rectum and colon inspected by means of FCS in the examined group of VCS (65,3 cm) is considerably shorter than the mean distance of the CRC diagnosed by means of VCS (91,25 cm). This, on its part, determines also the number of the patients (88 or 5,19%) with an undetected large bowel carcinoma and undetected polyps by means of FCS (105 or 6,19%). Along with undetected neoplasms, during FCS, synchronous carcinomas are not reported, too, while during VCS, a total of 88 neoplasms (5,19%) are established. Of these not established neoplasms, there are 26 which is 16,88% of all the carcinomas in the examined group or 1,53% of all the VCSs. The rest 62 cases (21,48%) are polyps sized over 10 mm, synchronous to the primary CRC. In sum, we establish 66 patients (42%) with a single colorectal carcinoma without any other neoplasms; 66 patients (42%) with a primary colorectal carcinoma and synchronous polyps sized over 10 mm, and 26 patients (16%) with a primary colorectal carcinoma and second synchronous one.

During this ten-year period, a total of 308 colorectal polyp patients, 147 males and 161 females, are diagnosed by means of VCS. The relative share of all the patients as a whole with a diagnosed colorectal polyp towards all the examined patients amounts to 18,17%. It is greater in males (20,44%) than in females (16,50%). The mean distance in all the colorectal polyp patients as a whole measured by means of VCS varies in broad limits - between 39,5 cm in 2014 and 72,86 cm in 2020 at a mean value of 57,23 cm. The mean colorectal polyp size

measured by means of VCS in all the patients as a whole varies in broad limits, too, between 6,4 mm in 2021 and 11,6 mm in 2019 at a mean value of 10,48 mm.

We classify the polyps analyzed by means of VCS and FCS into three groups: polyps  $\leq 5$  mm (46; 2,71%); between 6 and 9 mm (153; 5,54%), and  $\geq 10$  mm (109; 6,43%). Some 242 polyps (78,57%) of different size are established and 62 of them (21,48%) are associated with a primary CRC. In this analysis, the falsely-positive and falsely-negative results in VCS and FCS are studied in terms of the polyps detected. We establish 14 falsely-positive results (4,58%) and 8 falsely-negative ones (2,61%). By using of the error-matrix test algorithm, we determine a specificity of VCS for polyps of 82% and a sensitivity of 96% as well as a positive prognostic value of 93,99% and a negative prognostic value of 89,04%. During the detailed analysis of the different groups of polyps we find dependence between the sensitivity and specificity and polyp size. With size enlargement, VCS specificity and sensitivity increase, too. The sensitivity and specificity are 73,0% and 94,4% in polyps  $\leq 5$  mm, 84,1% and 95,6% in polyps sized 6-9 mm while 90,3% and 98,5%, respectively, in polyps  $\geq 10$  mm. The comparative analysis of FCS reveals a statistically significant difference in polyps less than 5 mm ( $p < 0,05$ ) on the account of FCS. We establish 46 polyps (14,93%) among 308 ones analyzed by VCS and 68 polyps (32,69%) among these detected by means of FCS. In the other two groups, there is no statistically significant difference between VCS and FCS ( $p > 0,05$ ).

The diagnostic accuracy of multi-slice spiral computed tomography is juxtaposed to that of colonoscopy in 23 patients with a synchronous CRC within a retrospective investigation during the period between September 19, 2014 and January 31, 2020 (Yang et al. 2022). The frequency of the proximal CRC omitted during colonoscopy is considerably greater than that of the distal CRC omitted (34,8% versus 4,3%). The frequency of the CRC of a medium large diameter (of 1,25 cm; in the interquartile range between 0,80 cm и 1,50 cm) omitted during the multi-slice spiral computed tomography is considerably smaller than that of the greater CRC of a long diameter (of 4,00 cm; in the interquartile range between 3,00 cm и 6,00 cm) omitted (Bian et al. 2020).

After the confirmation of the rectum cancer diagnosis by means of colonoscopy, the usage of both imaging methods of choice such as magnetic resonance imaging for the evaluation of the local and regional and computed tomography of the chest, abdomen and pelvis for the establishment of the

metastatic dissemination of the malignant disease, mainly in the form of lung and liver metastases, is imposed (Faouzi, Lucidarme 2022).

During the examination of 67 rectum cancer patients having undergone tumour resection and lateral lymph node dissection, pathological metastases in these lymph nodes are detected by means of magnetic resonance imaging in 18 patients (in 26,87%) but findings specific for the extramural venous invasion - in 32 patients (in 47,76% of the cases) (Abe et al. 2022). The multivariation analyses demonstrate that the higher risk for these metastases is statistically significantly associated with the magnetic resonance imaging of the extramural venous invasion ( $p=0,0112$ ) and with the shorter axis of the lateral lymph node ( $\geq 5$  mm) ( $p=0,0002$ ). The ratios of the positive probability of the magnetic resonance imaging of the extramural venous invasion only, of the size of the lateral lymph nodes only, and of the combination of these two factors are 2,12, 4,84, and 16,33, respectively. The patients with two absent risk factors each present with a statistically significantly longer relapse-free survival in comparison with the rest patients (84,4% versus 62,1%;  $p=0,0374$ ).

According to Cadi et al. (2022), computed tomographic colonographic angiography enables the examination of the distant colon cancer metastases, however, it has a limited diagnostic capacity in terms of the local and regional tumour dissemination. Not only a specific large bowel preparation but also a controlled CO<sub>2</sub> insufflation and intravenous contrast matter injection are necessary. The computed tomographic colonographic angiography provides a tridimensional view of the morphology of the whole large bowel and precisely locates the tumour site in it (Hiroishi et al. 2018). Merging the large bowel images with those of the vessels of the mesenterium and large bowel provides information about the anatomical variations of the vessels that helps the surgeon during the better planning of the colectomy. The twodimensional images of the computed tomographic colonographic angiography with slices perpendicular to the main axis of the colon segment with the tumour ensure a precise information about the extent of the parietal dissemination and are of benefit during the assessment of the value of the neoadjuvant chemotherapy (Cadi et al. 2022).

A system for visualization of the pathological areas omitted during the optical colonoscopy by means of a tridimensional reconstruction of VCS data is created proceeding from the fact that these two methods of imaging diagnosis are with one and the same geometry, however, they differ in terms of colour,

consistency and mirror reflections included into the optical colonoscopy (Mathew et al. 2021). The model of shared space is used for the creation of one and many mappings from VCS towards the optical colonoscopy and from the optical colonoscopy towards VCS.

Usage of computed diagnosis capacity for the purposes of colonoscopy enables the automatized detection of the colorectal polyps and the prognostication of the pathological alterations, namely, of the optical biopsy in the course of real-time endoscopy through which the omission or false diagnosis of the colorectal lesions can be avoided (Kudo et al. 2021).

Pre- and postoperative colonoscopy is accomplished in 518 out of a total of 1147 colorectal cancer patients having undergone a therapeutic open or laparoscopic colectomy in a national university hospital in South Korea during the period between January, 2012 and December, 2016 (Kim et al. 2016; Park et al. 2020). The total frequency of omitted adenomas amounts to 25,7% (between 22,2% and 29,8% at confidence interval of 95%). The juxtaposition between the patients with an optimal and those without an optimal large bowel preparation demonstrates a statistically significantly higher postoperative frequency of the polyps omitted ( $p < 0,001$ ). The optimal large bowel preparation enables the identification of more synchronous adenomas than the satisfactory preparation (odds ratio of 5,72) and the poor preparation (odds ratio of 11,39). The results from the univariation analysis show that patient's age and left-side colectomy influence upon the frequency of postoperatively omitted adenomas (Park et al. 2020).

Polyps sized over 1 cm are diagnosed by means of colonoscopy in 96 patients within a two-year investigation of 1981 samples from a total of 1038 patients at a mean age of  $67,2 \pm 12,7$  years (Adamiec et al. 2022). A pathohistological examination is carried out in 248 patients. The value of  $\geq 4$  according to Kudo's classification represents the best parameter for differentiation between benign and malignant lesions which are larger than 1 cm. It possesses a sensitivity of 91,2% and a specificity of 70,4%.

The results from the retrospective analysis of the colonoscopies performed by colorectal surgeons in a tertiary hospital centre in a total of 781 patients during the period between October 2018 and July 2020 demonstrate a frequency of detection of the colorectal polyps of 46% (Modi et al. 2022). A considerable difference in terms of this frequency and colonoscopy duration carried out in the morning or in the afternoon is absent.

In the colonoscopic registry of New Hampshire, USA, during the period between 2009 and 2019, data about a total of 42611 colonoscopies for colorectal polyps among individuals aged  $\geq 65$  years are established (Calderwood et al. 2022). The results from this observational study indicate that 17527 colonoscopies (41,13%) are screening, 19025 (44,65%) are for following-up and 6059 (14,22%) are for evaluation of the symptoms. The incidence rate of polyps at advanced stage increases with age advancement from 65 years to 69 years to that  $\geq 85$  years in terms of screening from 7,1% up to 13,6% ( $p=0,05$ ) but in terms of patients' following-up - from 9,4% up to 12,0% ( $p<0,001$ ). The continuation of the colonoscopic examinations of such polyps is recommended in 97,2% of the patients aged between 70 years and 74 years, in 89,6% of those aged between 75 years and 79 years, in 78,4% of those aged between 80 years and 84 years and in 66,7% of those aged  $\geq 85$  years.

## **6.2. Diagnostic role of virtual colonoscopy in other large bowel and extracolonic diseases**

During the examinations of the patients suspected for colorectal diseases by means of VCS, not only CRC and colorectal polyps but also a series of other diseases of the large bowel and rectum are diagnosed. Three different groups are defined: other benign colorectal diseases, benign extracolonic diseases, and malignant extracolonic diseases (Krause, Kruis 2019).

According to literature data, extracolonic findings reach up to 30% in the population aged up to 50 years and up to 65% in the patients examined after 70 years of age (Veerappan et al. 2010) with a positive predictive value of VCS for the extracolonic pathology of 95% (Wernli et al. 2013).

According to Popic et al. (2021), computed tomographic colonography surpasses the optical colonoscopy because of its non-invasive nature, better tolerability by the patient and its capacity for the examination of the extracolonic diseases (Popic et al. 2021). For all that ionizing radiation represents the most important burden of this imaging diagnostic method. In their review article, the authors comprehensively investigate the risks of this patient's irradiation and the introduction of various perfected imaging technologies such as automated

current modulation in the tube, filtered posterior projections, reduced current voltage in the tube and ultralow irradiation dosage.

The diagnostic value of the computed tomographic colonography with a mean value of the effective ultralow irradiation dosage of  $0,9\pm 0,4$  mSv and with a mean value of the standard non-enhanced irradiation dosage of  $3,6\pm 1,2$  mSv in terms of the extracolonic findings is analyzed in 49 patients with colorectal symptoms within a prospective investigation (Thorén et al. 2021). There is a statistically significant difference in favour of the standard irradiation dosage in terms of the detection as a whole of the simple, however, not in terms of the important reference extracolonic findings.

At least one extracolonic disease is identified by means of computed tomographic colonography in 304 out of a total of 502 patients (in 60,56% of the cases) in the course of a retrospective investigation during the period between January 1, 2010 and January 4, 2015 (MERCY Study Collaborating Group 2022). The results obtained support the hypothesis that the computed tomographic colonography is particularly useful for the detection of the clinically significant extracolonic findings among the symptomatic patients, among which, of the malignant diseases and life-threatening conditions such as abdominal aorta aneurysm at preclinical stage when they are pliable to a conservative or surgical treatment.

During this ten-year period, we diagnose by means of VCS several particularly common other large bowel diseases. The total number of these patients is 282. Firstly, it deals with diverticles - in a total of 157 patients (in 9,26% of the cases). Next follow stenosis in a total of 13 patients (in 0,77%), anastomosis in a total of 12 patients (in 0,71%), congenital large bowel anomalies and colitis in nine patients each (in 0,53% each), and Crohn's disease in three patients (in 0,18% of the cases). Other large bowel diseases are diagnosed in 79 patients (in 4,66% of the cases).

The number of the patients with other large bowel diseases diagnosed by means of VCS is greatest in 2016 (68 patients). Next follow the patients diagnosed in 2012 г. (42), in 2017 (40), and in 2013 (39 patients).

The relative share of the patients with other large bowel diseases diagnosed by means of VCS among all the patients examined by means of this method is greatest in 2019 (31,18%), in 2020 (26,23%), in 2021 (25,45%), and in 2016 (21,94%). The mean value of this relative share during the whole period amounts

to 16,64%. In the examined group, stenosis or occluding processes are rare (13 patients, 0,77%) as in the literature, data of 21,5% are cited (Horvat et al. 2018). Anastomoses or pseudostrictures (Regge et al. 2009) are detected in 12 patients (0,71%) which are postoperatively followed-up by means of VCS being a non-invasive and safe method preferred by the patients and indicating the colic and abdominal oncological status (Kim et al. 2010). The literature data analyzed indicate a sensitivity of following-up VCS of 97,2% after the oncological colorectal surgery, a negative predictive value of 100% as well as a sensitivity for the extracolonic relapses of 95%. Stenoses of benign nature such as diverticular stenoses occur in 10% to 30% from the population aged up to 50 years and between 30% and 60% after the age of 80 years. Along with the diverticular strictures, strictures after ischemia, Crohn's disease, postresectional, infectious and other pseudostrictures are described.

During this ten-year period, we diagnose by means of VCS a very great number of benign extracolonic diseases. The total number of these patients is 377 (22,24%). Along the patients with the ten most common benign extracolonic diseases, it deals with a total of 70 patients with more seldom diseases, too (with a total frequency of 4,13%). Most commonly, hiatal hernia is diagnosed - in 96 patients (in 5,66% of the cases). On the second and third place are liver hemangioma - in 46 patients (in 2,71%) and nephrolithiasis - in 45 patients (in 2,65% of the cases). Next follow cholelithiasis - in 33 patients (in 1,95%), ventral herniae - in 24 patients (in 1,42%), renal cyst - in 23 patients (in 1,36%), adrenal adenoma - in 17 patients (in 1,00%) and gynaecological tumours - in 14 patients (in 0,82% of the cases). Intraabdominal abscesses are established in nine patients (0,53%) but a dilated bile ducts with choledocholithiasis - in eight patients (при 0,47% of the cases).

The number of the patients with benign extracolonic diseases diagnosed by means of VCS is greatest in 2016 (127 patients). Next follow the patients diagnosed in 2017 (80), in 2014 (63), and in 2015 (59 patients).

The relative share of the patients with benign extracolonic diseases diagnosed by means of VCS among all the patients examined by means of this method is greatest in 2019, too (51,61%). Next follows this relative share in 2021 (43,64%), in 2016 (40,97%), and in 2020 (37,76%). Its mean value for the whole period amounts to 27,95%.



During this ten-year period, we diagnose by means of VCS a series of malignant extracolonic diseases. The total number of these patients is 104 (6,14%). Along the patients with the nine most common malignant extracolonic diseases, it deals with a total of 16 patients with six more seldom diseases (with a total frequency of 0,94%). The liver metastases from colorectal cancer identified in 31 patients (in 1,83% of the cases) play a leading role. A special attention is deserved not only by the patients with primary gynaecological carcinomas (in ten patients or in 0,59%), with kidney cancer (in seven patients or in 0,41%) and with primary liver cancer (in six patients or in 0,35%) but also by the cases with metastases in some other organs - in bones (in seven patients or in 0,41%), in the lung and in the peritoneum as well as with metastases from adrenal gland cancer (in six patients each or in 0,35% of the cases each).

The number of the patients with malignant extracolonic diseases diagnosed by means of VCS is greatest in 2016 (26 patients). Next follow the patients diagnosed in 2013 (23), in 2012 (21), and in 2015 (20 patients).

The relative share of the patients with malignant extracolonic diseases diagnosed by means of VCS among all the patients examined by means of this method is greatest in 2013 (11,33%). Next follows this relative share in 2015 (10,93%) and in 2012 (10,34%). It is very low in 2021 (1,82%). Its mean value for the whole period amounts to 8,02%. One should note here also the locoregional lymph basin and the distant lymph nodes as a part of TNM staging diagnosed and staged by means of VCS in contrast to FCS, that defines the operative methods and the postoperative follow-up and screening for risk groups (Veerappan et al. 2010).

Gluecker et al. (2003) categorize the extracolonic neoplasms and pathologies in three subgroups as during their investigation, 71 patients (10%) represent a clinically significant extracolonic pathology, 183 patients (27%) are of mean significance and 342 patients (50%) are of low clinical significance of the extracolonic pathology among a total of 681 patients examined by means of VCS. In nine patients (1,3%), a change of the surgical tactics is done (Gluecker et al. 2003).

In their study, Veerappan et al. (2010) establish by means of VCS an extracolonic pathology of 46% in a group of 2277 patients. Of them, 34,5% are clinically insignificant, while in 240 patients (11%) they are clinically significant as 11 of these patients are operated on by change of the operative plan.

During the ten-year period, a change of the operative strategy, or the resection surgery of CRC is changed or postponed because of the high clinical significance of the extracolonic pathology in nine patients (1,25%).

### **6.3. Diagnostic role of virtual colonoscopy in the choice of a surgical method**

During the recent several years, a more and more intensive publication output of the foreign authors devoted to the minimally invasive surgery in CRC patients is observed.

Within ROLARR randomized clinical trial of a total 466 patients with rectum adenocarcinoma from 29 centres in ten countries performed during the period between January 7, 2011 and September 30, 2014 г., Jayne et al. (2017) juxtapose the robot-assisted and conventional laparoscopic surgery in terms of the risk for conversion to open laparotomy. The total frequency of this conversion amounts to 10,09% (in 47 patients) as it is higher after the laparoscopic (in 28 out of 230 patients or in 12,17%) than after the robot-assisted surgery (in 19 out of 236 patients or in 8,05% of the cases) (standardized odds ratio of 0,61; between 0,31 and 1,21 at confidence interval of 95%;  $p=0,16$ ). The total frequency of the positive peripheral resection lines amounts to 5,79% (in 27 patients) as it is higher after the laparoscopic (in 14 out of 224 patients or 6,25%) than after the robot-assisted surgery (in 12 out of 235 patients or 5,11%) (standardized odds ratio of 0,78; between 0,35 and 1,76 at confidence interval of 95%;  $p=0,56$ ) (Jayne et al. 2017).

In the data-base of the retrospective multicentre cohort trial for minimally invasive surgery in the oncological right hemicolectomy (MERCY) during the period between 2014 and 2020, a total of 1870 patients are included (MERCY Study Collaborating Group 2022). A laparoscopic operation is performed 87,2% and in 68,1% of them, an extracorporeal anastomosis is created. After 2017, there is a clear tendency for an increase of the frequency of the intracorporeal anastomosis and robot-assisted surgery. The relative share of the extracorporeal anastomosis in the centres equipped with a robot-assisted surgical system amounts to 41%. The various models of regression analysis performed in 1088 patients show that gender, age, body mass index, accompanying diseases, robot-assisted

operations, intracorporeal anastomosis and conversion to open surgery are prognostic factors for the operative results. The intracorporeal anastomosis prognosticates a shorter period until the introduction of the initial nutrition of the patients and a smaller frequency of the infections at the site of operation. According to the results from an inquiry investigation, the intracorporeal anastomosis is preferred over the extracorporeal one on the part of 72% of the surgeons. The usage of carbon nanoparticles one day prior to the laparoscopic right hemicolectomy considerably improves the lymph dissection in comparison with the control group ( $p < 0,01$  and  $p < 005$ ) as well as the pathoanatomical classification (Pan et al. 2018).

Warps et al. (2022) juxtapose the results from the usage of the elective minimally invasive surgery on the occasion of cancer of the colon or rectum in T1-T3 stage during the period between 2012 and 2018 in a total of 46095 patients in the Netherlands as well as in a total of 8819 patients in Sweden (Warps et al. 2022). The introduction of the minimally invasive surgery is done by approximately five years later in Sweden than in the Netherlands, however, with a more commonly applied robot-assisted surgery and with a smaller volume of the operations per one hospital. The frequency of the conversion to open surgery is higher in Sweden and the oncological and surgical results obtained are comparable with those in the Netherlands. The minimally invasive surgery in the Netherlands during the period between 2012 and 2013 leads to a higher frequency of the reoperations for colon cancer and of the repeated hospitalizations, however, to a lower frequency of the of the non-operative complications in rectum cancer than in Sweden during the period between 2017 and 2018.

Huang (2022) performs segmental laparoscopic colectomy with extended tridimensional apical dissection of the lymph nodes along the upper mesenteric blood vessels and their main branches in nine patients with colon transversum cancer. Mean operative time is 160 min (between 140 and 185 min), mean number of removed lymph nodes is 30 (between 25 and 39) and mean number of the removed apical lymph nodes is 5,9 (between 0 и 11). Restoration after the operation is smooth in all the patients thanks to the preservation of the ileocecal zone and of a part of the colon ascendens. Postoperative complications of third degree and higher according to Clavien-Dindo's classification are absent (Huang 2022).

Takorov et al. (2018) apply a total laparoscopic approach in CRC 25 patients with a synchronous liver metastasis, with a mean operative time of 223 min (100-415 min) and with a total blood loss of 180 mL (100-300 mL). Postoperative hospital stay is 6,8 days (6-14 days). Postoperative complications are observed in 6 patients (22,2%). It is generalized that simultaneous laparoscopic colorectal and liver resection seems to be safe, feasible and with satisfactory short-term results in selected patients with CRC and a synchronous liver metastasis (Takorov et al. 2018).

Ou et al. (2022) apply three techniques of the laparoscopic approach for the intersphincteric resection of low rectal cancer in a total of 235 patients during the period between October 2010 and September 2016. Transabdominal access is used in 142 patients, transabdominoperineal access - in 57 patients, and transanal access with pulling out - in 36 patients. Shorter operative times and less blood loss are observed with the first and third access when compared with the second one. The anatomical distance is shorter with the second and third access than with the first one. Three accesses do not differ between each other in terms of operative safety, operation outcome, or anal sphincter functions (Ou et al. 2022).

The analysis of the Asian Endoscopic Surgical Society shows that intraoperative FCS in case of unclear anatomy and absent tactile sensation enables the determination of the tumour localization and mucous infiltration. An intraoperative FCS in a unclear tumour localization; stenosing left colon CRC and leak tightness check of the colorectal anastomosis are demonstrated (Liu et al. 2020).

Teo et al. (2022) report a female patient at a mean age with synchronous adenocarcinoma of the left flexura and malignant polyp in the middle part of the rectum in whom a successful anterior laparoscopic resection is carried out according to Deloyers' procedure first described in 1964. Proximal transection is performed in the middle part of colon transversum while distal transection is done in the low part of rectum. An anastomosis between the middle part of colon transversum and the distal rectum is created preceded by intraoperative fluorescence with indocyanine green. Finally, a protective ileostomy is created located 40 cm from the ileocecal valve (Teo et al. 2022).

During the period between January 2017 and October 2010, Liu et al. (2022) perform a modified anterior laparoscopic resection of the rectum with preservation of the left colonic artery without any additional abdominal incisions for

exanteration of the transanal material in 22 patients. In five of them, simultaneously, a bitruncular ileostomy is carried out. Postoperative catabolic process of the patients lasts, on the average, three days (between two and seven days). In six patients, one observes a postoperative stenosis of the anastomosis, in four patients - a postoperative fistula of the anastomosis, and in one patient - a postoperative bleeding from the anastomosis. In 17 patients in the course of follow-up, obvious symptoms or signs of relapses or metastases are absent (Liu et al. 2022).

Sun et al. (2022) elaborate an approach with a priority to the fascial space of the fascia of the ureterohypogastric nerve and to the vesicohypogastric fascia, two vitally important embryological planes on the lateral compartment of the pelvis during the accomplishing of the total laparoscopic pelvic exanteration in strictly selected patients with locally advanced rectum cancer. The operation is related to a reduced intraoperative blood loss and a smaller frequency of postoperative complications (Sun et al. 2022).

The laparoscopic operation performed in 85 patients aged over 80 years on the occasion of CRC in Japan is associated with a statistically significantly smaller frequency of the postoperative complications as a whole ( $p=0,0343$ ), of these of degree  $\geq 2$  according to Clavien-Dindo ( $p=0,0015$ ), and of the infections at the site of the operative wound ( $p=0,0015$ ) in comparison with open surgery (Yoshimatsu et al. 2021). According to the results from the multivariation analysis, the laparoscopic operation (odds ratio of 0,19; between 0,05 and 0,75 at confidence interval of 95%;  $p=0,0177$ ) and the absent pulmonary dysfunction (odds ratio of 0,24; between 0,06 and 0,96 at confidence interval of 95%;  $p=0,0441$ ) are statistically significantly associated with the reduced risk for postoperative complications of degree  $\geq 2$  according to Clavien-Dindo's classification. The laparoscopic operation is significantly associated with the improved survival, too, when excluding the mortality rate immediately related to CRC in patients with pulmonary dysfunction ( $p=00020$ ), or with poor functional status ( $p=0,0412$ ).

The influence on the results from the total mesorectal laparoscopic excision of the rectum cancer localization is investigated in 176 pairs of patients (with anterior and with non-anterior localization) in the course of a monocentre retrospective study during the period between 2011 and 2016 in China (Wu et al. 2022). According to the results from the multivariation analysis, the ventral localization is an independent risk factor for the local relapses (hazard ratio of

12,6;  $p=0,006$ ), total survival (hazard ratio of 3,0;  $p<0,001$ ), and disease-free survival (hazard ratio of 23;  $p=0,001$ ). This localization is a prognostic factor for the more common local relapses and the poorer survival in the patients in stage II/III or stage T3/T4 of the disease. The local relapses are more seldom among the patients in stage II/III (in 1,4%) or stage T3/T4 (in 1,5% of the cases) with a non-ventral localization of the disease.

Resection of colon transversum with D2 lymph node dissection is carried out after preliminary VCS-3D reconstruction with good results as a part of a simulation-reconstructive plan prior to minimally invasive operations (Narushima et al. 2019). Iguchi et al. (2022) investigate the results from the extended laparoscopic right hemicolectomy and laparoscopic resection of colon transversum performed in a total of 129 patients with cancer in the middle part of colon transversum within a multicentre retrospective trial during the period between January 2008 and December 2019 in Japan. The first operation is done in 35 and the second one in the rest 94 patients. The first operation is with a statistically significantly longer operative time (202 min versus 185 min;  $p=0,026$ ) and with a by little bit higher frequency of the complications of  $\geq 3$  degree according to Clavien-Dindo's classification (11,4% versus 3,2%;  $p=0,086$ ). Anastomosis insufficiency develops in three patients (in 8,6% of the cases) during the first operation only as the difference is statistically significant ( $p=0,018$ ). Total three-year survival is similar in both patients' groups (at stage I: 100% versus 91,9%;  $p=0,64$ ; at stage II: 100% versus 95,5%;  $p=0,46$  and at stage III: 100% versus 88,2%;  $p=0,91$ , respectively) (Iguchi et al. 2022).

During this ten-year period we operate on a total of 715 patients with a diagnosed CRC. Open surgery prevails - in 603 patients (in 84,34% of the cases). Laparoscopic surgery is performed in 83 patients (in 11,61%) and a robot-assisted operation with a da Vinci Xi surgical robot - in 29 patients (in 4,06% of the cases) while both methods are united as minimally invasive (MI) surgery in 122 patients (15,66%).

The analysis of the annual dynamics of the number of open operations indicates its considerable predominance during the first two years in comparison with the last two years - not only in terms of the males operated on (106 versus 66) and of the females operated on (66 versus 37) but also of all the patients operated on as a whole (172 versus 103 patients). Only the total number of the patients

operated on as a whole in 2012-2013 is statistically significantly greater than that of the patients operated on as a whole in 2020-2021 ( $t=2,261$ ;  $p<0,05$ ).

We establish a statistically significant increase of the number of the laparoscopic operations during the last five years (between 2017 and 2021) in comparison with the first five years (between 2012 and 2016) not only among the males operated on ( $t=2,648$ ;  $p<0,02$ ) but also among the patients as a whole operated on ( $t=2,501$ ;  $p<0,02$ ).

Robot-assisted surgery is introduced in the First Clinic of Surgery at St. Marina University Hospital of Varna single joint-stock company in 2019. During the three-year period (between 2019 and 2021), with this modern method a total of 17 males (58,62%) and 12 females (41,38%) with CRC are successfully operated on.

Nowadays there is a durable increase of the number of CRC patients undergoing these two minimally invasive surgical interventions on the account of the open operations. As a whole, the relative share of all the patients of ours operated on with laparoscopic and robot-assisted surgery during the period between 2019 and 2021 amounts to 31,67%. It is by a little bit greater among males (33,08%) than among females (29,67%).

In the group of VCS, 136 CRC patients (19,02%) are operated on. Of them, 21 patients (2,93%) undergo minimally invasive surgery. These patients are generalized as group-1 (with VCS). The rest CRC patients are diagnosed by means of other methods without VCS and are united in group-2 (without VCS). Their total number is 579 (80,98%) as of them, 91 patients (12,73%) are operated on through MI surgery. The operative protocols are analyzed in terms of the operative plan and intraoperative diagnosis. A statistically significant difference in terms of the tumour localization between both groups with MI surgery is established as in MI with VCS, the preliminary operative plan is implemented in 95,23% while in the group with MI without VCS, this operative plan is achieved in 85,71% of the patients ( $p<0,05$ ). This analysis is done between both groups with MI surgery because of the absent tactile sensation during the localization of the tumour process. This has imposed to perform intraoperative FCS in 3,29% of the cases in group-2 MI without VCS, too.

VCS provides an exact localization of the primary process along with CT reconstruction of the whole colon and rectum. Some 154 primary carcinomas are detected as when compared with FCS, they are by 88 more (57,14%) ( $p<0,05$ ). It is

also due to the incomplete endoscopies (62,32%). We establish rectum carcinoma in 55 patients (35,71%) followed by carcinoma of the left colon (sigmoid colon and colon descendens) in 51 patients (33,12%) and 11 patients (7,14%), respectively. In the right colon, carcinoma of cecum prevails - in 15 patients (9,74%). There are 14 cases (9,09%) with carcinoma of colon transversum, four (2,60%) of flexura lienalis, three - of colon ascendens (1,95%) and one (0,65%) of flexura hepatica. By means of FCS, a rectum carcinoma is established in 27 patients (40,91%), a sigmoid colon one in 22 patients (33,33%), of colon descendens one in 8 patients (12,12%), of colon transversum one in 6 patients (9,09%), of cecum one in 2 patients (3,03%), and of colon ascendens one in one patient (1,52%). There are statistically significant differences in right carcinoma localizations when VCS and FCS are compared ( $p < 0,05$ ). This is confirmed by the examined mean distance in FCS which is 61,05 cm from the anal edge and represents a precondition for missed detection or impossible reaching the pathological processes which are located proximally from this mean distance.

Being a computed tomographic method, VCS enables the diagnosis of stenosing malignant or benign processes and provides a detailed description of the vascular anatomy, too. Thus 26 synchronous CRCs (16,88%) among 154 primary cases as well as 109 colorectal polyps sized over 10 mm (35,38%) are established. Of them, 66 polyps (21,42%) are synchronous with CRC. This leads to the change of the operative strategy consisting of extension of resection volume, resection of two segments, resection with colostomy, or subtotal resection. The primary carcinomas of left colon-rectum with synchronous of left colon, synchronous to colon transversum and synchronous to right colon prevail and amount to 22 (88%) of all the synchronous carcinomas. The rest 12% are distributed between primary carcinoma of right colon with synchronous of right colon and synchronous of colon transversum. In the examined group, no primary CRC of colon transversum with synchronous of colon transversum is detected. The CRCs with synchronous polyps sized over 10 mm of left colon and colon transversum prevail - in 56% of the cases.

The vascular anatomy is analyzed by means of VCS in all the 29 patients (2,93%) undergoing preparation for MI surgery (group-1, MI). Their preoperative planning includes a detailed analysis of the vascular anatomy of arteria mesenterica superior and vena mesenterica superior in right localizations and of arteria mesenterica inferior and vena mesenterica inferior in left localizations of the



pathological process as well as the regional lymph basin. The control group of MI operations without VCS includes 91 patients (12,73%). All the patients undergo minimally invasive methods of treatment, including robot-assisted surgery in 11 from group-1 (MI) and 4 from group-2 (MI). The following results are comparatively analyzed: operative time, time prior to vascular dissection, lymph nodes removed, lesion of large vessels such as arteria mesenterica superior, vena mesenterica superior, arteria mesenterica inferior, and vena mesenterica inferior, conversion, insufficiency, perioperative mortality rate, intraoperative mortality rate, and hospital stay. In terms of the operative time, there is no statistical difference between the examined groups as it is 205 min in group-1 and 237 min in group-2. The removed lymph nodes prevail in group-1 with VCS being 19 on the account of 11 in the control group and there is no statistical significance ( $p>0,05$ ). A greater number is observed due to the preliminary information available about a vascular localization and high ligation of the vessels that on its part is a precondition for extension of the lymph node dissection. The hospital stay is comparable in both groups being within  $11\pm 6$  days in group-1 (MI) and  $10\pm 6$  days in group-2 (MI). There is no perioperative mortality. There is difference in terms of the analyzed time for reaching the vascular dissection which is shorter (of 63 min) in group 1 ( $p<0,05$ ). It deals with the time from the primary incision to the first vascular clasp or stitcher. The preliminary plan for port position, the exact localization of the tumour process and clear vascular anatomy contribute to this result, too. Magistral vessel lesions are higher in group-2 without VCS (12 or 13,18%) ( $p<0,05$ ), and correspondingly, the frequency of the conversions is greater in the control group (9 or 9,90%) in contrast to group-1 with VCS in which conversion is imposed in one case only (4,76%) ( $p<0,05$ ). There is no insufficiency in the group examined by means of VCS while nine patients operated on (9,90%) are established in group-2 without VCS ( $p<0,05$ ). This is due to the clear preoperative vascular anatomy, resection at preserved arches, anastomosis with good blood supply and absence of tension. We establish that in right hemicolectomies, arteria ileocolica and arteria colica media are constant in anatomical plane while arteria colica dextra is revealed as a single branch in six patients only (20,69%). In the left resections, C variant is established in 16 patients (84,21%) with single branches of left colic artery, sigmoid artery, and arteria rectalis superior. Prior to the operative intervention, VCS enables the planning of the optimal port position in dependence on patient's individual characteristics and

the optimized docking of DaVinci Xi robot, thus the collisions (internal and external) are reduced to a minimum.

During the retrospective study of Haraikawa et al. (2021), the computed tomographic values of every image of every blood vessel are measured. They are statistically significantly higher in the patients in whom CO<sub>2</sub> is used for bowel dilatation not only in terms of the sigmoid artery ( $p=0,034$ ) and left colic artery ( $p=0,045$ ) but also of the upper ( $p=0,003$ ) and lower mesenteric vein ( $p=0,019$ ), the sigmoid vein ( $p=0,046$ ), the left colic vein ( $p=0,24$ ), and the middle colic vein ( $p=0,036$ ) (Haraikawa et al. 2021).

The results from the three-year follow-up of the outcome from the tridimensional laparoscopic colectomy in 47 consecutive patients and from the twodimensional laparoscopic colectomy in 44 consecutive patients with colon cancer operated on during the period between October 2015 and November 2017 in Taiwan are followed-up (Yang et al. 2022). There are no essential differences between both groups in terms of patients' characteristics, data from the operations, pathological results, postoperative complications, operative time duration, blood loss quantity, and number of the lymph nodes removed. Besides, both disease-free survival and total survival are equal in these two patients' groups.

The results from the robot-assisted and laparoscopic right hemicolectomy are retrospectively analyzed in a comparative aspect in a total of 4977 patients with right colon cancer in Australia (Clarke et al. 2022). A total of 4831 patients undergo laparoscopic while 146 patients undergo robot-assisted surgery. The duration of the hospital stay is statistically significantly shorter (five versus 6,9 days;  $p=0,01$ ) and the number of the lymph nodes dissected is greater (22 versus 19;  $p=0,04$ ) while the frequency not only of the surgical (5,9% versus 14,2%;  $p<0,004$ ) but also of the nonsurgical complications (4,6% versus 11,7%;  $p<0,007$ ) is less in the robot-assisted than in the laparoscopic operation.

A total of 40 consecutive patients with rectum neoplasms undergo robot-assisted or laparoscopic transanal minimally invasive surgery during the period between January 2012 and April 2017 (Lee et al. 2019). During the robot-assisted operation, there is tendency towards operative blood loss reduction. Mortality is absent in both groups. The robot-assisted surgery is associated with a statistically significant cost increase - by US\$ 880. The mean direct costs for the laparoscopic operation amount to US\$ 356 while those for the robot-assisted one - to US\$ 4440,92 as the difference is statistically significant ( $p=0,04$ ) (Lee et al. 2020).

The clinical and oncological results from the application of the robot-assisted and conventional laparoscopic right colectomy in two groups of 35 patients each presenting with adenocarcinoma or adenoma of the right colon in a university hospital in the city of Madrid, Spain, are juxtaposed within a prospective nonrandomized trial during the period between October 2013 and October 2017 (Ferri et al. 2021). The operative time is statistically significantly longer during the robot-assisted operation (243 min versus 179 min;  $p < 0,001$ ). The total hospital costs do not significantly differ between the robot-assisted and the laparoscopic operation (9455,14 Euro versus 8227,50 Euro;  $p = 0,21$ ).

The short-term and distant results from the application of the robot-assisted and laparoscopic radical right hemicolectomy are analyzed in a total of 232 patients with adenocarcinoma of the right colon during the period between October 2014 and October 2020 in a profile university hospital in China (Zhang et al. 2022). There are 56 patients in the first and 176 patients in the second group. The total operative time ( $206,9 \pm 60,7$  min versus  $219,9 \pm 56,3$  min;  $t = -1,477$ ;  $p = 0,141$ ) and the total frequency of the perioperative complications (17,9% versus 22,7%,  $\chi^2 = 0,596$ ;  $p = 0,465$ ) are similar in both operations. In the first group, a statistically significantly less intraoperative blood loss ( $50 \pm 20$  mL versus  $50 \pm 50$  mL;  $Z = -4,591$ ;  $p < 0,01$ ) and a greater number of lymph nodes dissected ( $36,0 \pm 10,0$  versus  $29,0 \pm 10,1$ ;  $t = 4,491$ ;  $p < 0,01$ ) are established. In the patients of the first group, it deals with a statistically significantly shorter hospital stay ( $t = -2,888$ ;  $p < 0,05$ ), a shorter interval prior to the occurrence of first flatus ( $t = -2,946$ ;  $p < 0,05$ ) and of the first defecation ( $t = -2,328$ ;  $p < 0,05$ ). Not only the total three-year survival (92,9% and 87,9%) but also the three-year disease-free survival (83,1% and 82,6%) do not statistically significantly differ between the first and the second group of patients ( $p > 0,05$ ) (Zhang et al. 2022).

The mean operative time in 20 patients undergoing robot-assisted total colectomy/total proctocolectomy is by approximately one hour longer than that in 36 patients undergoing laparoscopic procedures in Asan Medical Centre in the city of Seoul, South Korea, as this difference is statistically significant ( $p = 0,003$ ) (Kim et al. 2020). This is mainly due to the additional time needed for the installation of the instruments and to the more common transitory ileal diversion. Conversion to open surgery is imposed in three patients only (in 8,33% of the cases) undergoing laparoscopic operation. Short ileal reservoirs (8 cm of length) are applied in all the

patients with ileal-pouch anal anastomosis during the robot-assisted operation, however, in one patient with laparoscopic surgery only.

## 7. CONCLUDING REMARKS

The colorectal carcinoma is a disease representing an increasing problem for public health worldwide. The radical surgical resection is considered the golden standard and within the complex of multimodal therapy, it offers the most realistic chance for healing. The introduction of the miniinvasive surgery is a great evolution which enables the radical resection of colon and rectum with a minimal traumatism.

The imaging methods play a key role in the preoperative diagnosis for detection, localization, staging, preoperative plan, presence or absence of accompanying pathology, and following-up. The virtual colonoscopy is a method of choice meeting the requirements of the preoperative preparation.

In contrast to the conventional, the miniinvasive colorectal surgery is applied in single specialized clinics in our country only. This is a complex endoscopic or robot-assisted operation requiring knowledge of and experience in compound laparoscopic and robot-assisted techniques as well as perfection in conventional surgery. These minimally invasive operative techniques should be performed only in hospital institutions with rich experience in the resection colorectal surgery and by surgeons with expert laparoscopic and robot-assisted skills.

The correct selection of the patients, the perfecting of the surgical techniques, the adequate preoperative staging and the postoperative treatment and care are the main methods for the reduction of the postoperative complications and first-rate factors for the improvement of the results from the treatment of the patients with colorectal carcinoma.

The present dissertation work outlines the role of the virtual cononoscopy in the minimally invasive and robot-assisted oncological colorectal surgery. It has been supported by the European Fund for Regional Development through the Operative Programme ‘Science and education for intelligent growth’ according to contract No BG05M20P001-1.002-0010-C01(2018-2023).

## 8. CONCLUSIONS

1. The virtual colonoscopy is characterized by a high specificity and sensitivity in T1-T3 carcinomas.
2. The virtual colonoscopy has a significant role in the establishment of the synchronous neoplasms and it is a method of choice in case of incomplete optical colonoscopy.
3. The virtual colonoscopy is characterized by a high specificity and sensitivity in polyps sized over 6 mm.
4. The large bowel and extracolonic diseases established by means of VCS directly influence upon the choice of the surgical method.
5. The staging by means of VCS provides a clear T-stage, exact localization, precise locoregional status and detailed vascular anatomy..
6. The virtual colonoscopy minimizes the probability of change of the operative plan and reduces the frequency of conversion and perioperative complications.
7. In the patients having undergone a preoperative VCS, statistically significant benefits for the exact staging of the oncological disease and the choice of an optimal radical operative method are rendered an account.

## 9. CONTRIBUTIONS

- For the first time in Bulgaria, the role of the virtual colonoscopy in minimally invasive colorectal operations is analyzed.
- A ten-year period with a great number of diagnosed, operated on, and followed-up patients is analyzed.
- Literature and clinical data about the advantage of the virtual colonoscopy during the preoperative diagnosis of the colorectal neoplasms are presented.
- A retrospective clinico-epidemiological monocentre investigation is performed and contemporary data about the frequency and clinical characteristics of colorectal carcinoma patients are presented.
- A detailed imaging and clinical investigation of the influence on the operative methods of the virtual colonoscopy is carried out.
- A comparative analysis between a noninvasive imaging method and optical endoscopy which is the golden standard in the colorectal diseases is made.
- The increase of the minimally invasive and robot-assisted surgery in the treatment of the colorectal diseases is confirmed.

## **10. FUTURE DIRECTIONS**

- Virtual colonoscopy usage in 3-D modelling for port positioning during robot-assisted surgery and for intraoperative navigation.
- The virtual colonoscopy combined with a high-specific tumour marker could occupy a leading position in colorectal carcinoma screening.



## 11. PUBLICATIONS

1. Hadzivelev M. Virtual colonoscopy and fibrocolonoscopy in colorectal cancer patients. *Varna Medical Forum*, 2022;11(1):119-126 (in Bulgarian).
2. Hadzivelev M. Virtual colonoscopy and fibrocolonoscopy in colorectal polyp patients. *Varna Medical Forum*, 2022;11(1):127-134 (in Bulgarian).

## 12. APPENDIX

### TNM classification of the colorectal carcinoma

Tx	Primary tumour can not be defined.
T0	No data about any primary tumour.
Tis	Carcinoma in situ, intraepithelial, or invades lamina propria.
T1	Tumour with invasion into the mucosa.
T2	Tumour with invasion into muscularis propria.
T3	Tumour with invasion into muscularis propria and passing into serosa.
T4	Tumour with invasion into neighbouring organs or structures.
T4a	Tumour penetrating through the visceral peritoneum.
T4b	Tumour with direct infiltration into neighbouring organs or structures.
Nx	Regional lymph nodes can not be defined.
N0	No metastases in the regional lymph nodes.
N1	There are metastases in 1 up to 3 regional lymph nodes.
N1a	There are metastases in 1 lymph node.
N1b	There are metastases in 2 - 3 regional lymph nodes.
N1c	Although there are no metastases in regional lymph nodes, tumour deposits are detected in submucosa, mesangial or peritoneum-covered paracolic and pararectal tissue.
N2	There are metastases in 4 or in more than 4 regional lymph nodes.
N2a	There are metastases in 4 up to 6 regional lymph nodes.
N2b	There are metastases in more than 7 regional lymph nodes.
M0	There are no distant metastases.
M1	There are distant metastases.
M1a	Distant metastases in one organ (liver, lung, outside the regional lymph node).
M1b	Distant metastases in more than one organ.
M1c	Peritoneal metastases with or without metastases in other organs.
GX	It can not be defined.
G1	Well-differentiated.
G2	Moderately differentiated.
G3	Low-differentiated.
G4	Non-differentiated.

## Colorectal carcinoma staging

0	Tis	N0	M0
I	T1	N0	M0
	T2	N0	M0
IIA	T3	N0	M0
IIB	T4a	N0	M0
IIC	T4b	N0	M0
IIIA	T1-T2	N1/N1c	M0
	T1	N2a	M0
IIIB	T3-T4a	N1/N1c	M0
	T2-T3	N2a	M0
	T1-T2	N2b	M0
IIIC	T4a	N2a	M0
	T3-T4a	N2b	M0
	T4b	N1-N2	M0
IVA	Any T	Any N	M1a
IVB	Any T	Any N	M1b
IVC	Any T	Any T	M1c

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