

CT Colonography – Overview of Current Clinical Practice

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Abstract

CTC is a diagnostic method that has been developed for more than a decade and there is a large number of studies conducted to describe its capabilities. By using new generations of CT devices and advanced software, colon analysis is possible in a relatively short time. On the other hand, high sensitivity for detecting polyps and the possibility of detecting bowel abnormalities make CTC an interesting and desirable method. The aim of this article is to determine the advantages and disadvantages of CTC, as well as its role in colon cancer screening. Compared to colonoscopy, CTC is a less invasive technique that does not require sedation. In addition to its advantages, CTC is associated with several disadvantages. A review of research proved a very small percentage of complications that can occur during the procedure, and the main limitation is ionising radiation. Despite this, it is used for numerous indications and plays a role in detection of colorectal cancer. Due to the fact that colon cancer is a major problem in the world, its frequency and mortality are trying to be reduced by screening methods. Compared to other diagnostic methods, CTC is described as a pleasant and safe examination. Considering the available data, CTC represents an ideal balance due to minimal invasiveness and high sensitivity. With the advancement of technology, CT devices and software, the role of CTC will most probably grow significantly and secure its important place in healthcare.

Keywords: CT colonography; colon; colorectal cancer; screening program

Abbreviations and acronyms: CAD (computer-aided detection), CRC (colorectal cancer), CTC (computed tomographic colonography), FOBT (fecal occult blood test), FS (flexible sigmoidoscopy), IR (iterative reconstruction), LD CTC (low dose computed tomographic colonography), ULD CTC (ultra-low dose computed tomographic colonography)

Introduction

Malignant diseases are a major health problem in the world, and the number of patients and deaths is increasing year by year. Prevention, diagnosis and treatment therefore represent an important role for the most successful treatment and disease control. Colorectal cancer (CRC) is one of the main causes of death in the world, and in Croatia it ranks second. In men, it is behind lung cancer, and in women before breast cancer [1]. The development of cancer is slow, and its early detection and treatment is possible by using prevention methods. Such procedures are called screening methods and are carried out among healthy and at-risk population. Patients in whom CRC is detected at an earlier stage have a 90% chance of survival, while patients with advanced disease only have a 10% chance [2]. Some countries practise the use of computed tomographic colonography, CTC, as a screening method and it represents a combination between classic

colonoscopy and computed tomography. In addition to the name CTC, today it is also called virtual colonoscopy, and it represents a fast, safe and less invasive technique than colonoscopy [3].

The evolution of CTC is closely related to the technological progress of the device and the development of reconstruction software. Today's CT device consists of a gantry, a table, a high-frequency generator, a control desk with a computer and an image storage device [4]. The first data from the application of CTC appeared in the 90s, and in 1994 Vining and Gelfand were the first to perform a 3D visualisation of the colon using a CT device. At that time, the name virtual colonoscopy was not used, due to the lack of a virtual display. A few years later, the application of three-dimensional display followed, which became the basis [5]. Improvements in computer equipment have enabled advanced 3D endoscopic images, real-time data evaluation, and the application of computer-aided detection, CAD [6].

In addition to a detailed analysis of the colon, CTC is used after an incomplete colonoscopy, when diagnosing colorectal cancer, after a positive fecal test and cancer resection, and after polypectomy [7]. Despite numerous indications, some of the contraindications are related to allergies to contrast agents, claustrophobia and pregnancy. Also, inflammatory conditions of the patient represent a risk during the examination [8].

CTC begins with the preparation of the patient, who implements a certain diet the day before the examination. Also, bowel preparations are performed to remove retained stool that can cover bowel abnormalities and lead to false findings [9]. When the patient is placed in the correct position, the physician introduces air through the tube, and the table begins to move through the scanner. During the examination, the patient is also turned to the opposite side, and the examination is completed when the image is displayed on the computer screen. Once the scan is done, the physician or technologist will remove the tube. Scanning in a certain position takes about 10 seconds, and the entire search takes about 15 minutes [10].

The aim of the article

The aim of this article is to describe the value of CTC as a diagnostic method and the numerous indications for which it is used. A detailed analysis and comparison of the research in the last ten years shows its advantages and disadvantages. Also, its potential role as a screening method for the detection of colorectal cancer is presented.

Discussion

Advantages of CT colonography

CTC has been developed and improved for decades in order to reach its diagnostic value and enable the highest quality analysis. The main advantages of a virtual colonoscopy, in contrast to a conventional one, are [11]:

- The examination time is shortened to 10-15 minutes, unlike a conventional colonoscopy where the examination lasts 50 minutes
- It is more comfortable for patients due to the absence of the use of a colonoscope
- No sedation drugs are needed
- The patient has no side effects and can recover very quickly after the examination
- Lower risk of colon perforation

Diagnostic importance of CT colonography

The results of the CTC examination in most studies were compared with colonoscopy, which represents the reference standard. Among the first studies is the study by Pickhardt et al. CTC has been described as a method whose sensitivity is similar to colonoscopy. The results showed a value of 88.7% for detecting polyps with a diameter of 6 mm and a sensitivity of 96% for polyps with a diameter of 10 mm. Colonoscopy showed a sensitivity of 79% for 6 mm polyps and a sensitivity of 87%. In conclusion, CTC has been shown to be an excellent method for detecting lesions and polyps in at-risk individuals [12]. A

few years after the first study, Pickhardt et al. conducted a meta-analysis of available research. The sensitivity of CTC when detecting cancer was a high 96%. The obtained result was compared with colonoscopy and indicated the superior position of CTC. Also, through a systematic review and meta-analysis of the data, it was established that no polyp or potential cancer was left unrecognized [13].

Since incomplete colonoscopy is one of the main indications, it is important to determine the role and diagnostic value of CTC. Pullens et al. compared the results obtained by colonoscopy and subsequent CTC. An incomplete colonoscopy was the result of a bowel bend and a fixed colon, and patients were sent to additional examinations. Of the total results, CTC revealed 19 new polyps and 27 additional bowel lesions [14]. A similar study was conducted by Maggialelli et al. in which they retrospectively analysed 61 patients with abdominal pain who had previously undergone an incomplete colonoscopy. Colon abnormalities were detected in 24 patients, and the examination was described as non-invasive and pleasant. Also, due to the speed of information gathering and non-use of sedation, CTC was presented as a method with numerous advantages after an incomplete colonoscopy [15].

Image analysis

Two-dimensional and three-dimensional images, as the final result of CTC, complement each other. The size of the detected polyp is extremely important for further treatment and diagnosis, and a combination of both views is used when measuring them. The 3D interpretation enables the detection of a large number of polyps, even those that are difficult to find and see. 2D view is used to confirm abnormalities and accuracy of results. New 3D visualisation options include the use of 3D tools such as virtual dissection, panoramic views and various projections. On the other hand, it is also possible to monitor 3D endoluminal surface in order to examine areas that were not visible before (Figure 1) [16].

A review of the research found low detection of polyps when using only 2D imaging, and that is why most institutions insist on their combination. Two studies, Philip

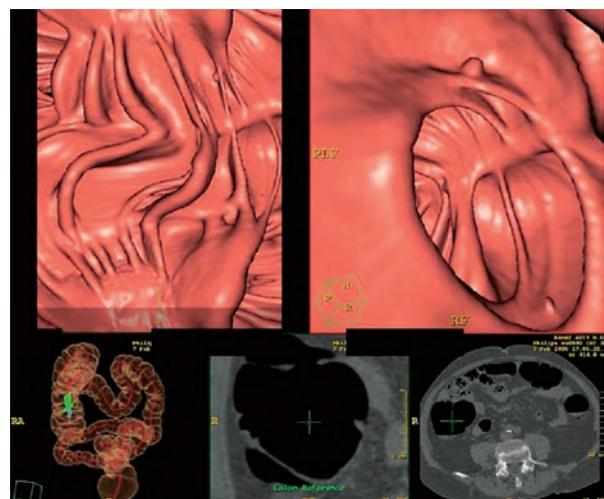


Figure 1. 2D and 3D visualization of the colon
Source: <https://d3i71xaburhd42.cloudfront.net/05eb1a9516ef774cc7af711c94359d73bcf9315c/5-Figure1-1.png>

et al. [17] and Schmidt et al. [18], report sensitivity values of 2D and 3D views. Philip et al. compared the results with regard to the size of the polyps. They described that the sensitivity of 2D imaging for polyps up to 6 mm in size is 44.1%, while 3D imaging has a sensitivity of 85.7%. For polyps larger than 10 mm, the sensitivity of 2D imaging was 75%, and for 3D imaging 92% [17]. Schmidt et al. took into account sensitivity values only for polyps above 10 mm. The sensitivity of the 2D view was shown in values of 55% – 66%, while the 3D view included values above 93% [18].

Computer-aided detection

New technical and software advances are applied in the fields of medicine and are also related to CTC. Software for computer-aided detection is used to reduce errors in image interpretation and to find additional polyps. Study from 2013. compared image analysis with and without the use of CAD. The sensitivity of CTC without computer software was 65%, while the sensitivity using it was 76%. In conclusion, the addition of CAD to image analysis has been found to offer numerous advantages in the detection of polyps, even with relatively small sizes [19].

Disadvantages of CT colonography

Despite the constant growth in technology and software, it is important to emphasize the potential problems and pitfalls associated with CTC. The main disadvantages compared to conventional colonoscopy are [11]:

- Inability to remove the polyp, which is why the patient is sent for a colonoscopy
- Risk of allergic reactions when using contrast
- The patient is exposed to a certain dose of radiation
- Various contraindications

Complications of CT colonography

A review of the literature determined the number of possible complications during the examination. Bellini et al. conducted the first meta-analysis of available research. The aim of the research was to determine complications and the number of colon perforations. 11 articles and a total of 100,000 patients were reviewed. Perforation was found in 28 patients, which is 0.04%. Despite their existence, CTC was associated with a low complication rate. It is important to emphasize that the review of studies did not describe any deaths [20]. Research has been conducted around the world to find out the side effects of virtual colonoscopy. The first national survey was conducted in Italy, where a questionnaire was sent to hospitals where CTC was frequently performed. The incidence and level of complications arising in clinical practice were assessed. Out of a total of 40,000 examinations, perforation was recorded in 7 of them and was asymptomatic. As a percentage, it amounts to 0.02% and represents a very good result. Also, no deaths occurred during the examination [21]. Another national survey was in Japan where an online survey was conducted. As in previous studies, no deaths were recorded. The number of perforations was distinguished depending on the procedure, and of the total complications, 81% of perforations did not require treatment [22].

Radiation dose

The risk of patients undergoing CTC is ionising radiation [23]. Given that virtual colonoscopy is increasingly used as a replacement of colonoscopy, it is important to determine the radiation dose. In Table 1. CTC is compared to various radiological examinations. As a rule, doses used during CTC are lower compared to colonoscopy. The reason lies in natural contrast between soft tissue, introduced gas and the rest of the stool. Regarding other procedures, virtual colonoscopy leads to greater exposure to radiation with respect to classic X-ray procedures [24].

Table 1. Comparison of different ionizing radiation doses for different examinations [24]

Examination	Ionizing radiation dose [mSv]
Lung X-ray	0,1
Abdominal X-ray	1
Barium enema fluoroscopy exam	9
CT abdomen and pelvis (w/o contrast)	10
CTC (2 series)	20
CTC ultra low-dose protocol	2

CT: Computed tomography;

CTC: Computed tomography colonography

Dose reduction can be achieved with the help of software and image reconstruction. With their help, protocols of low doses, LD and ultra-low doses, ULD, are enabled. Cianci et al. described the radiation dose, image quality and the possibility of polyp detection using both protocols. By comparing the results no major differences were found, and the quality of the image itself remained at the same level. Regarding the radiation dose, ULD-CTC, compared to LD CTC, reduced the radiation level by 63% [25]. Two studies, Taguchi et al. [26] and Millerd et al. [27] analysed dose reduction using iterative reconstruction, IR. They came to the conclusion that IR can increase the quality of the image and at the same time reduce the radiation dose. The total radiation dose was reduced by 60% with the help of image reconstruction software.

Artefacts of CT colonography

Artefacts during CTC present problems. The study by Lefer et al. [28] and Ricci et al. [29] describes artefacts as traps that affect image quality. Both studies led to the realisation that the misdiagnosis of the artefact as a pathological condition exposes the patient to new tests and a greater amount of radiation. The study by Lefer et al. related the artefacts to the technical characteristics of the device, the patient's anatomy, and the analysis of 2D and 3D images. Patient preparation protocols and the importance of a combination of 2D and 3D views are mentioned as a solution [28]. On the other hand, Ricci et al. described patient-generated artefacts in detail. Motion has been identified as one of the main causes of artefacts. The movement of the patient, the heartbeat or peristalsis of the intestines



Figure 2. Motion artifact on the 2D image
Source: <https://pubs.rsna.org/cms/10.1148/rg.2020190078/asset/images/large/rg.2020190078.fig1b.jpeg>

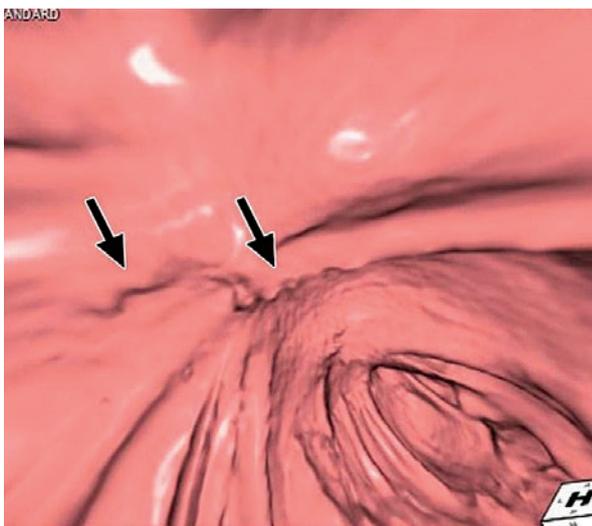


Figure 3. Motion artifact on the 3D image
Source: <https://pubs.rsna.org/cms/10.1148/rg.2020190078/asset/images/large/rg.2020190078.fig1a.jpeg>

influenced their formation. On the 2D view, they appear as blurred areas (Figure 2), while on the 3D images they appear as areas of weaker attenuation (Figure 3). By advising the patient to rest and follow the breathing instructions, their elimination is possible [29].

Methods of screening

Colorectal cancer, CRC, is one of the most common cancers in the world, affecting both men and women. Although the incidence in the population is high, its occurrence and development can be prevented if detected in time. The problem is represented by a wide range of available methods with different values of sensitivity, invasiveness and cost (Figure 4). Many studies have described the sensitivity of colonoscopy for detecting cancer and compared it with CTC. By comparing the obtained research results,

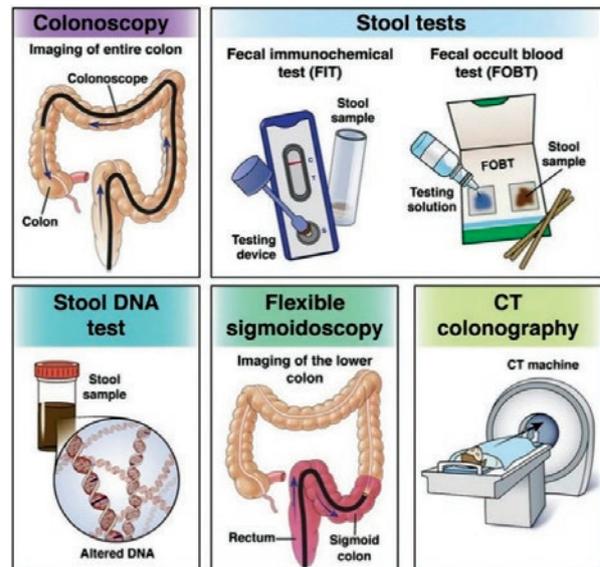


Figure 4. Available methods for colorectal cancer screening
Source: https://els-jbs-prod-cdn.jbs.elsevierhealth.com/cms/attachment/a5a960eb-5bb7-44ab-906c-99043ae300dc/gr1_lrg.jpg

their similarity was established and, among other things, improved CTC results. Accordingly, CTC was included as an additional screening method. Due to less invasiveness, the possibility of examining the entire colon and without the use of sedation, it is used more and more frequently in the world [30].

CT colonography as a screening method

The literature was searched in order to reveal the accuracy, acceptability and safety of CTC as a screening method for colorectal cancer. In 2008, the American Cancer Society added CTC to the list of recommended screening methods for colorectal cancer [5]. In addition, there are several Food and Drug Administration reviewed and approved or cleared choices for colorectal cancer screening, with the most recent being approved in 2021 [31].

Described studies revealed a high diagnostic value of CTC for polyps larger than 6 mm. With the subsequent use of software capabilities and the combination of 2D and 3D views, CTC has an advantage over colonoscopy. Accordingly, an examination of the entire abdomen and pelvis is also possible. One of the advantages of using CTC as a screening method is safety. The risk of perforation is in a higher percentage related to colonoscopy, while no serious complications were recorded for CTC [32]. However, there are a number of shortcomings regarding the CTC and screening program. A detailed analysis revealed that misunderstanding and lack of information on the part of the patient leads to their occurrence. The fear of the presence of radiation is one of the main problems. Disinformation that exists has caused irrational fear and reduced response to the screening program. Accordingly, many studies are available which are supported by evidence of no connection between cancer and exposure to radiation dose on CTC, which is very low. By using image reconstruction, the dose is further reduced. Since CTC is used in the adult population, the risk of potential problems is much lower compared to the benefits [32].

Obaro et al. described CTC as a minimally invasive method. Due to its safety and the fact that there were no recorded deaths, it was being included in the screening system. Concerns related to the search were raised due to the presence of radiation. Many researchers emphasised that there is no evidence that radiation leads to the emergence of new diseases. Furthermore, the study raised a question related to the biopsy. If polyps were noticed, the patient would have to be sent for a colonoscopy for their excision. However, it was decided that polyps up to 10 mm do not pose a danger and their monitoring is sufficient. As a conclusion, it was described that when using CTC, it is important to establish a standardised protocol and ensure quality control. If all components of the examination are ensured, successful detection of lesions can be achieved [33]. De Haan et al. described the role of CTC in population screening. They mentioned the combination of 2D and 3D views as additional benefits of virtual colonoscopy. Despite the fact that the 2D view enables a faster analysis and consequently a shorter duration of the search, the 3D interpretation has a higher sensitivity for the detection of lesions. Their combination enables a more detailed analysis. By using CAD algorithms, the interpretation of findings increases its value [34]. Pooler et al. compared the patients experience and the degree of participation in the screening program. They conducted a 12-question survey in 3 different institutions. The main reasons for choosing CTC for screening were non-invasiveness, the possibility of quick recovery and no use of sedation. Out of the total number of respondents, 60% of the population rated their experience as excellent, and 2.2% as bad (Figure 5). Also, of the patients who decided to participate in the screening method again, 88.5% indicated that they would choose CTC, while 11.5% indicated colonoscopy. The final results have showed satisfaction with CTC and it was found that the response to screening increased by 55% compared to screening where colonoscopy was used [35].

According to available information from the institutions where CTC is performed in the Republic of Croatia, in the very beginning it was not used on a daily basis, while in recent years it has been used more and more.

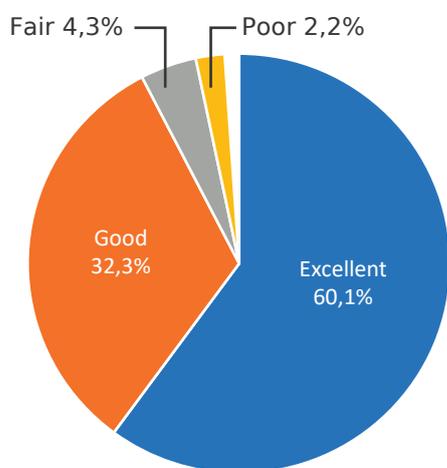


Figure 5. Patient experience with CT colonography
Source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3689205/bin/nihms467738f3.jpg>

The growth tendency of this test as a screening method is mainly in private institutions [36] [37].

Comparison with other screening methods

Two studies, Lin et al. [38] and Sali. et al. [39], were carried out for the purpose of a systematic examination of the accuracy, but also the disadvantages of colon cancer screening methods. Lin et al. included fecal occult blood test, FOBT, flexible sigmoidoscopy, FS, colonoscopy and CTC in the study. With regard to the ability to detect cancer and the risk of consequences, each method differed. Data obtained from population studies revealed that FS significantly reduces mortality from CRC. Despite this, it is not widely used. The risk of radiation was mentioned as a disadvantage of virtual colonoscopy, and colonoscopy was associated with complications such as perforations and bleeding. For all diagnostic tests, adherence to the screening program is the most emphasised as a problem [38]. Sali. et al. conducted a study on CRC screening using FOBT, virtual colonoscopy, and colonoscopy. FOBT was presented as a simple and cheap method, but false positive and negative findings are mentioned as a disadvantage. In contrast, CTC and colonoscopy provided insight into the colon, but were associated with complications. Colonoscopy was shown to be the gold standard although the response rate was quite low. The specialty of CTC was related to the visualisation of organs located outside the colon. Detection of so-called extracolonic findings is shown in a high percentage and is considered an advantage of CTC. Despite this, the optimal screening method has not been chosen [39]. The study by Senora et al. compared the experience of patients undergoing FS and CTC. Patients had to fill out a survey regarding the feeling of discomfort and degree of anxiety during the examination. Also, they were asked to report side effects if they notice them. A significant difference was related to bowel preparation during CTC, which was rated as moderately unpleasant, and in addition, it prolonged the examination time. Nevertheless, both tests were accepted as tolerable [40].

Can CT colonography replace colonoscopy in the detection of colorectal lesions?

Given that CTC evolved from colonoscopy, their comparison and advantages and disadvantages have always been analysed. Although colonoscopy has been declared the gold standard for detecting polyps and cancer, it is an invasive examination associated with complications and bleeding. The procedure is detailed, but it can skip 10%-20% of polyps. The search may remain incomplete if there is an obstruction of the large intestine or a tumour. This is precisely why CTC serves as an alternative [41]. Extracolonic findings, identification of the location of the tumour, and a lower degree of error and false findings are just some of the mentioned advantages. On the other hand, the great advantage of colonoscopy will always remain related for not using ionising radiation. Studies conducted to reduce radiation dose during CTC used low dose protocols and tube modulation technique. Based on data from the literature, colonoscopy and CTC are two examinations with very similar diagnostic values. However, sensitivity and accuracy vary with polyp size. It is accepted that colonoscopy has an advantage when visualising polyps

smaller than 6 mm, while CTC has a weaker result. In the detection of larger lesions, the accuracy of CTC is identical to colonoscopy [41]. Time passed from the discovery to the implementation of virtual colonoscopy as a medical examination, but only in recent years the question of its use as a screening method for colorectal cancer arisen. High precision for the detection of colorectal polyps and comparative diagnostic values with colonoscopy, but with a lower degree of complications, made it an acceptable method. According to the examined patients, CTC is the preferred method for cancer screening. Due to its tolerability, less invasiveness, less fear of complications and pain, it was considered a better choice. Despite the fact that colonoscopy remains the gold standard today, CTC secured its place in the world of medicine and the future with its results [41].

Conclusion

Over the past few years, numerous options for using CTC have been developed. As a method related to computed tomography, it will always remain associated with technological advances and improvements with CT devices. New generations of devices have enabled significantly

faster examinations and improved reconstruction images. The advantages of CTC include safety and the application of new software options. Today, there are possibilities of applying CAD tools that facilitate the visualisation of polyps and abnormalities despite the twists and turns of the colon. With this way of performing the examination image analysis time and the total time of examination will be reduced. Various studies have proven that despite its advantages, CTC has its limitations. One of the biggest is related to the patient's exposure to ionising radiation. However, by implementing new methods and using low-dose protocols, it is possible to limit and reduce the radiation dose. Despite the fact that the first indication is related to an incomplete colonoscopy, CTC is widely used as a screening method for colorectal cancer. Although it is preventable if detected in time, CRC remains a major cause of mortality worldwide. There is a large number of screening methods available that can be used, including CTC. Like any method, it has its advantages and disadvantages. A comparison of studies described that bowel preparation can negatively affect the acceptability of CTC as a screening test. However, as a solution, bowel preparations are available which reduce the patient discomfort. All things considered, CTC reflects the ideal balance of minimal invasiveness with high sensitivity. ■

CT Kolonografija – Osvrt na trenutnu kliničku praksu

Sažetak:

CTC je dijagnostička metoda koja se razvijala više od desetljeća i postoji veliki broj provedenih studija u svrhu opisivanja njenih mogućnosti. Upotrebom CT uređaja novih generacija te softverskim napredcima omogućena je analiza debelog crijeva u relativno kratkom vremenu. S druge strane, visoka osjetljivost za detekciju polipa te mogućnost otkrivanja abnormalnosti crijeva, CTC čine zanimljivom i poželjnom metodom. Cilj ovog rada je odrediti prednosti te nedostatke CTC, a ujedno i njenu ulogu prilikom probira karcinoma debelog crijeva. U usporedbi s kolonoskopijom CTC predstavlja manje invazivnu tehniku za koju nije potrebna sedacija. Osim svojih prednosti, CTC povezana je i s nekoliko nedostataka. Pregledom istraživanja dokazan je vrlo mali postotak komplikacija koje se mogu javiti tijekom postupka, a glavno ograničenje predstavlja ionizirajuće zračenje. Unatoč tome, koristi se za brojne indikacije te ima ulogu prilikom otkrivanja kolorektalnog karcinoma. Zbog činjenice da karcinom debelog crijeva predstavlja veliki problem u svijetu, njegova učestalost i smrtnost pokušava se smanjiti metodama probira. S obzirom na ostale dijagnostičke metode, CTC je opisana kao ugodna i sigurna pretraga. Uzimajući u obzir dostupne podatke, CTC predstavlja idealnu ravnotežu zbog minimalne invazivnosti, a visoke osjetljivosti. Napretkom tehnologije, CT uređaja i softvera, uloga CTC značajno će rasti i tako će osigurati svoje važno mjesto u zdravstvu.

Ključne riječi: CT kolonografija; debelo crijevo; kolorektalni karcinom; program probira

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