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A Comparison between Colonoscopy and Computed Tomography Colonography in Detection of Colorectal Neoplasia

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Thesis Approval

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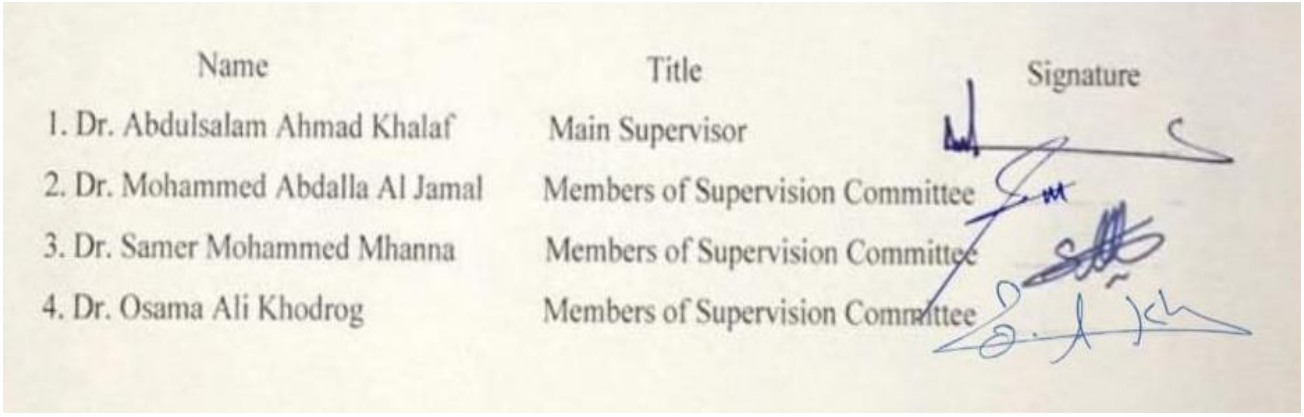

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Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is substantially my own work and has not been submitted for any other degree at the Arab American University or any other institution.

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Dedication

To my God, a person dear to my heart, and my family, whose unwavering love, support, and support have served as the cornerstones around which my academic career has been constructed. Your confidence in me and your sacrifices have motivated me to accomplish this goal. This thesis is evidence of our group's resiliency and strength. I'm grateful that you have always been my lighthouse.
I dedicate this work to you, with boundless gratitude and love.

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This work is dedicated to each of you, with profound appreciation and gratitude.

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Abstract

Introduction

Colorectal cancer (CRC) is the third most diagnosed cancer and cause of cancer-related deaths in the USA, particularly affecting men under 50. In Palestine, CRC is the second most common cancer, with a rising incidence rate. Colonic polyps, which can lead to CRC, are categorized as neoplastic or non-neoplastic, with adenomas potentially becoming malignant. Early detection through screening like colonoscopy (CS) is vital for preventing CRC. Computed tomography colonography (CTC), a less invasive alternative to CS, provides similar accuracy but requires proper preparation for effective screening, with a sensitivity comparable to CS for detecting colorectal abnormalities.

Purpose

The study aims to assess the effectiveness of CT colonography (CTC) compared to optical colonoscopy (OC) in detecting colorectal neoplasia in Palestinian hospitals and to improve diagnostic methods.

Methods

The study retrospective cross-sectional quantitative analysis aimed to compare the sensitivity of CTC with optical colonoscopy (OC) for detecting colorectal neoplasia in patients. The study analyzed 68 patients using retrospective data (2019-2024) from four hospitals at An-Najah National Hospital, Martyr Khalil Suleiman Hospital, Iben Sina Specialized Hospital, and Al-Razi Hospital. Participants had colorectal polyps or cancer and underwent CTC under suboptimal preparation. Statistical analysis compared CTC and OC sensitivities.

Results

CTC detected 78.6% of masses but failed to detect any polyps, with a weak agreement (Cohen's $\kappa = 0.235$) between CTC and OC. Sensitivity for colorectal neoplasia detection was only 36.3%, with a high error rate of 63.7%.

Conclusion

CTC demonstrated moderate sensitivity for mass detection but was ineffective in identifying polyps. These findings highlight the need for adherence to international protocols to improve the accuracy of CTC for comprehensive colorectal screening.

Keyword: Colonoscopy, CTC, Colon Cancer.

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List of Definitions of Abbreviations

Abbreviations	Title
AAUP	Arab American University
AAA	Abdominal aortic aneurysms
AAP	Adenomas with Advanced Pathology
ACR	American College of Radiology
AJCC	The American Joint Committee on Cancer
ALARA	As Low As Reasonably Achievable
BMI	Body Mass Index
BSGAR	The British Society of Gastrointestinal and Abdominal Radiology
CAD	Computer Aided Detection
CCE	Colon capsule endoscopy
CO2	Carbon Dioxide
Cr	Creatine
C-RADS	The CT Colonography Reporting and Data System
CS	Colonoscopy
CT	Computed Tomography
CTC	Computed Tomography Colonography
CTC-A	Computed Tomography Colonography Angiography
CT-TAP	Computed Tomography for Thorax-Abdomin-Pelvic
ECFs	Extracolonic findings
ESGAR	European Society of Gastrointestinal and Abdominal Radiology.

ESGE	The European Society of Gastrointestinal Endoscopy
FDA	Food and Drug Administration
FIT	Fecal Immunochemical Test
FOV	Field of View
GE	General Electric
gFOBT	Guaiac-Based Fecal Occult Blood Test
HDI	Human Development Index
HU	Hounsfield Unit
IM	Intramuscular
IV	Intravenous
K	The Kappa coefficient
kVp	peak kilovoltage
LLD	Left Lateral Decubitus
mA	Milliampere
MDCT	Multi Detector Computed Tomography
MgC	Magnesium Citrate
MR	Magnetic Resonance
MRI	Magnetic Resonance Imaging
NaP	Sodium Phosphate
NCI	National Cancer Institute
NCTCTAP	National CT Colonography Training and Accreditation Programme
NHIS	National Health Interview Survey

NHS	National Health Service
OC	Optical Colonoscopy
PET	Positron Emission Tomography
PHIC	Palestinian Health Information Center
RANZCR	The Royal Australian and New Zealand College of Radiologist
RCR	The Royal College of Radiologists.
RLD	Right Lateral Decubitus
SPSS	Statistical Package for the Social Sciences
T	Tesla
TNM	Tumor Node Metastasis
UK	United Kingdom
USA	United State of America
USPSTF	The United State Preventive Services Task Force
VRT	Volume Rendering Technique
2D	Two Dimensional
3D	Three Dimensional

Chapter One: Introduction

1.1 Background

In the United States, CRC ranks third in terms of both incidence and mortality from cancer-related causes for both men and women. It is the primary cause for men under 50 and the second most common cause of cancer-related fatalities overall. More than half of CRC deaths and cases are associated with modifiable risk factors such as smoking, poor diet, excessive alcohol consumption, physical inactivity, and being overweight. Regular screening, surveillance, and high-quality treatment can prevent a significant portion of CRC cases and deaths (Siegel et al., 2023).

Globally, CRC was diagnosed in about 1.9 million people in 2020, With over 900,000 deaths from cancer, it ranks as the second most common cause of cancer-related deaths. CRC primarily affects older adults, so the number of cases and deaths is expected to rise due to population growth and aging. This trend may worsen as CRC incidence increases in younger people due to rising rates of overweight and obesity. However, population-based screening methods, such as endoscopic and stool-test-based screening, can prevent a significant share of CRC cases (Klimeck et al., 2023).

According to the latest Ministry of Health annual report for 2022, CRC is the second most common cancer in Palestine (West Bank), the incidence rate 15.3 case per 100000 of total population, percentage 12.9 %. and in 2019 incidence rate 14.8 case per 100000 of total population, percentage 12.6 %.

In general, CRC is the second leading cause of death in Palestine in 2022, with 55% of deaths occurring in males and 45% in females. The total number of reported cancer deaths was 2,147, which lung, colorectal and breast cancers percentage as follows 16.4%, 14.3 %. 11.7 % respectively (Palestinian Health Information Center (PHIC) et al., 2020, 2023).

Colonic polyps are mucosal growths that extend into the lumen of the gastrointestinal tract. While they are usually asymptomatic, larger polyps can lead to obstruction, ulceration, and bleeding. They are categorized into neoplastic types (such as adenomas and carcinomas) and non-neoplastic types. Gastrointestinal polyposis syndromes, which are often hereditary, are associated with an increased risk of cancer.

Adenomas over 1 cm, with villous structures, high-grade dysplasia, or any combination, are termed adenomas with advanced pathology (AAP) (Hakim, 2021).

ACR Practice Parameter suggests a 0.6 cm threshold for CTC polyps reporting, and provides guidelines for accurate measurements. Lesions 5 mm or smaller (diminutive) are typically benign tubular adenomas hyperplastic polyps, or residual stool. Polyps are categorized based on their size large (≥10 mm) and small (6–9 mm). Hyperplastic polyps, which have a serrated appearance but no dysplastic features, do not present a risk for cancer transformation. Tubular adenomas, the most common type of adenomatous polyps, are benign but can potentially become malignant.

Polyps are further categorized by morphology: Sessile polyps (Broad-based lesions), Pedunculated polyps (Polyps with a visible stalk), Flat or non-polypoid lesions Typically, <3 mm in vertical elevation, including laterally spreading tumors (previously known as carpet lesions), which can exceed 3 mm in height and are commonly seen in the rectum and right colon (Yee et al., 2024).

CRC generally originate from previously benign adenomas. Various studies have proposed hypotheses regarding the transformation of adenomas into cancer. The majority of colon tumors arise through a multistep process characterized by a sequence of morphological, histological, and genetic changes that build up over time. This progression from benign polyp to malignant cancer underscores the importance of early detection and removal of adenomas to prevent the development of colorectal cancer (Simon, 2016).

Improving patient survival depends on the early detection of premalignant lesions like colorectal polyps, due to the potential progression of these polyps to carcinoma over time. Detecting and removing polyps at an early stage can prevent the development of CRC and significantly improve patient outcomes and survival rates.

Screening and diagnostic approaches for colorectal neoplasia include a range of techniques, including stool occult blood tests, barium enemas contrast (single and double), colonoscopy and sigmoidoscopy. Of these, CS is considered the gold standard for identifying colorectal neoplasia and for examining asymptomatic individuals at high risk. Nonetheless, it presents limitations, including incomplete visualization of the entire

colon in approximately 5% of patients and potential blind spots due to its unidirectional movement, which can lead to missed lesions.

Furthermore, colonoscopy is unable to assess organs outside of the colon. Complications associated with colonoscopy, such as perforation, major bleeding, bacteremia, and anesthesia-related cardiopulmonary issues, are possible, with severe complications occurring in a small percentage of cases.

CT rapidly developed since its discovery in 1994 by Vining, is an imaging modality relying on CT scans with helical thin-section of a colon that has been cleaned and enlarged. These scans undergo processing using computer systems to generate multi-planar two dimensional and virtual endoscopic three-dimensional displays, enabling the detection and evaluation of colorectal abnormalities (Devir et al., 2016).

CTC offers a minimally invasive option to OC, and comes with several benefits. It does not require sedation, does not cause bleeding during the procedure, and has a decreased chance of perforating the colon (around 2 out of every 10,000 examinations). Unlike OC, CTC does not pose a risk of infection from an improperly cleansed colonoscope. However, if colonic pathology is found, CTC demands further OC and does not permit tissue sampling.

CTC is frequently employed to finish colonic screening when an OC is incomplete and serves as the main direct visualization method for patients with complex medical conditions that heighten the risk of sedation or procedural perforation/ bleeding.

The sensitivity of CTC and OC in identifying colorectal cancer is similar, with CTC at 96% and OC at 95%. The main objective of visual screening using CTC or OC is to remove and detect the polyps and identify colon cancer in its early stages.

While most polyps are benign, adenomatous polyps are the precursors to most colon cancers through the well-established "adenoma-carcinoma" sequence. Thus, the goal is to find and eliminate polyps before they develop into cancer (Ricci et al., 2020).

CTC holds promise in cancer screening due to its noninvasive nature and its ability to offer a complete set of high-resolution rectum and colon images. The detection of

colorectal cancer has improved because to advancements technique of images processing, have led to positive health outcomes in detecting colorectal cancer.

When utilizing CTC to identify colorectal cancer, a number of requirements must be satisfied for high diagnosis accuracy. These include using fecal tagging, making sure the intestinal lumen is sufficiently dilated, and doing the proper pretreatment to maximize the acquisition circumstances.

Collapsed colonic segments can be mistaken for annular tumors or may make it more difficult to detect lesions, therefore adequate dilation of the colon is especially important to get results that are sufficient for diagnosis. Therefore, optimizing these conditions is essential for the effectiveness of CTC in colorectal cancer screening (Sakamoto et al., 2014).

1.2 Problem statement

Colonoscopy is the gold standard for therapeutic and detecting colorectal polyps and cancer but has limitations like blind spots and risks of complications and incomplete the Procedure. CTC is a less invasive alternative with benefits such as no sedation, reduced bleeding, and lower risk of infection, but it requires follow-up OC if abnormalities are found. Both OC and CTC are effective in cancer detection with similar sensitivity (95-96%) (Ricci et al., 2020).

CTC requires proper preparation for accurate results, and poor preparation can lead to missed diagnoses, impacting treatment and increasing costs (Sakamoto et al., 2014).

1.3 Aims and Objectives

This retrospective study aims to evaluate CT scan detectability the colorectal neoplasia, and the effectiveness of current patient preparation protocols and CTC imaging techniques in Palestinian hospitals for detecting colorectal cancer and polyps. The study seeks to identify strategies to enhance the detection of colon neoplasia and improve overall diagnostic efficiency.

This study's main goal is to compare the outcomes of colorectal CS and CTC for the same patients, who underwent both tests within a consecutive period, without direct

intervention by the researcher in conducting patient examinations. This comparison aims to assess the accuracy and consistency of CTC as a diagnostic tool for detecting colon diseases, including cancer and polyps, in comparison to the established standard of colonoscopy. The study intends to evaluate the reliability of colonography in clinical practice without influencing patient care directly during the examination process.

Understanding the accuracy and consistency of the protocols used in hospitals can help improve their efficiency and prevent errors, thereby enhancing the accuracy of diagnostic results. This evaluation can also support the implementation of a CTC program for detecting tumors and polyps as an alternative to colonoscopy.

By assessing the effectiveness of current protocols, hospitals can identify areas for improvement and implement measures to enhance protocol efficiency. This proactive approach can lead to more accurate diagnoses and better patient outcomes. Additionally, establishing a CTC program as an alternative to colonoscopy can offer patients a less invasive option for colon disease screening, potentially increasing accessibility and compliance with screening recommendations. This strategic shift towards CTC can further contribute to improving diagnostic capabilities and overall healthcare quality.

1.4 Hypotheses of research

It is hypothesized that the CT device used in Palestinian hospitals will yield high accuracy, efficiency, and sensitivity in detecting colon neoplasia including cancers and polyps, comparable to colonoscopy in identifying various shapes and sizes of colon neoplasia.

1.5 Questions of research

- In Palestinian hospitals, how sensitive is CTC in identifying colon neoplasia in comparison to colonoscopy performed with pooled bowel preparation?
- How can the CT device achieve high sensitivity in detecting colon neoplasia?
- What interventions can improve the sensitivity of computed tomographic imaging for colon lesions in patients with poor bowel preparation?
- Do the current CTC reports provide effective diagnoses of the patients' conditions?
- Is the CT device capable of detecting colon neoplasia?

1.6 Outline

Chapter (1): Introduction.

Chapter (2): literature review

Chapter (3): Methodology of the research.

Chapter (4): The results.

Chapter (5): The discussion & and conclusion.

Chapter Two: Literature Review

2.1 Introduction

This study investigates the sensitivity and detectability of CT scanners in Palestinian hospitals for detecting colorectal neoplasia. In this chapter, several topics related to this investigation will be explored, including the anatomy of the colon, types of polyps, colorectal cancer: epidemiology and diagnosis, screening for colorectal neoplasia, colonoscopy: procedure and importance, and CT in colorectal neoplasia detection.

Published research from PubMed, websites of international organizations, Google Scholar, and textbooks was utilized as part of the study's search strategy.

2.2 Theory

2.2.1 Colon

The colon measures roughly 120 to 200 cm in length, extending from the cecum to the sigmoid colon. It includes the descending colon, ascending colon, sigmoid colon and transverse colon.

The gastrointestinal tract features a central lumen surrounded by layers the muscularis, serosa, submucosa, and mucosa layers. The mucosa comprises the epithelium, lamina propria (rich in blood and lymph vessels), and muscularis mucosa. The submucosa is made up of blood vessels, connective tissue, and a submucosal nerve plexus. The muscularis layer consists of circular and longitudinal muscle layers, with the myenteric nerve plexus situated between them. The serosa is a thin connective tissue layer.

In the colon, the mucosa lacks layers except in the rectum, containing long intestinal glands with many goblet and absorptive cells. Absorptive cells, with cylindrical microvilli, aid in water absorption and mucus secretion. The abundant bacterial population in the lamina propria results in a high concentration of lymphatic cells and nodules.

The muscularis has longitudinal and circular layers, forming taenia coli. The anal region has rectal columns, and enlarged blood vessels can cause hemorrhoids. The colon's mucosa is essential for digestion and nutrient absorption, while muscular contractions move waste (Singh et al., 2017; Takayanagi et al., 2018; Vogel et al., 2022).

2.2.1.1 Colorectal Surgery

The location of the lesion determines the incision lines for colorectal cancers. Understanding proximal, distal, and radial margins, and lymphadenectomy, has improved surgical outcomes. Colon resections, performed 4 to 5 cm from the lesion, include the entire area supplied by a major artery to ensure successful lymphadenectomy. The anus, where the colon opens outside, is controlled by involuntary smooth muscle and voluntary striated muscle sphincters. Colorectal surgery focuses on precise resection considering vascular and lymphatic anatomy (Marti et al., 2019; Patroni et al., 2016).

2.2.1.2 Digestive Waste and Defecation

Nutrient waste moves through the colon to the rectum, where it is stored as stool. When stool accumulates in the rectum, it triggers the urge to defecate, prompting the individual to do. so Various factors, including medications, pregnancy, stress, illness, a persistent urge to defecate, diet low in fiber and fluids, lack of exercise, can disrupt the natural rhythm of the intestines, causing waste to move too quickly or too slowly. The anus, the external opening of the colon, is regulated by two sphincters: the internal anal sphincter, which is composed of smooth muscle and functions involuntarily, and the external anal sphincter, made of striated muscle and under voluntary control (Guend et al., 2017; Muro et al., 2019).

2.2.1.3 Vascular and Lymphatic Supply of the Colon

The large intestine is irrigated by the inferior and superior mesenteric arteries. The superior mesenteric artery supplies blood to the appendix, cecum, ascending colon, and the right transverse colon two-thirds. The inferior mesenteric artery provides blood to the left third of the transverse colon, descending colon, sigmoid colon, rectum, and upper anal canal.

Branches of these arteries extend through the muscle layers and terminate in the circular smooth muscle of the bowel wall. Most venous drainage occurs through the hepatic portal vein via the superior and inferior mesenteric veins, with a small part of the rectum draining into the internal iliac and pudendal veins via the middle and inferior rectal veins (Denham et al., 2012).

2.2.1.4 Lymphatic Drainage of the Colon

The colon's lymphatic drainage and arterial supply coincide. The proximal transverse colon, ascending colon, and cecum all have lymphatic arteries that drain into nodes linked to the superior mesenteric artery, whereas the rectum, distal transverse, and sigmoid colon have lymphatic vessels that drain into nodes linked to the inferior mesenteric artery.

The lymph nodes are divided into four groups: epicolic (on the serosal surface), paracolic (along the medial borders and mesenteric borders), intermediate (along major arteries), and preterminal (between the inferior and superior mesenteric arteries' primary trunks). In terms of the drainage hierarchy, the para-aortic nodes are regarded as the highest. The lymphatic fluid progresses from nodes close to the colon to higher-order nodes, with significant redundancy at lower levels, making it challenging to identify sentinel lymph nodes (Denham et al., 2012).

2.2.2 Polyps

Polyps are mucosal growths that extend into the lumen of the gastrointestinal tract. Although colonic polyps are generally asymptomatic, large ones can cause complications such as obstruction, ulceration, and bleeding. These polyps are categorized into neoplastic (including adenomas and carcinomas) and non-neoplastic types.

Gastrointestinal polyposis syndromes, frequently inherited and linked to a higher chance of developing cancer, also exist. Adenomas and carcinomas share cellular dysplasia as a common characteristic, although they differ microscopically.

Serrated polyps are viewed as intermediate because they have malignant potential, though they may be classified as non-neoplastic when associated with hyperplastic polyps. Submucosal lesions resemble polyps coated in normal mucosa but are not true polyps.

Adenomas larger than 1 cm, those with a villous structure, high-grade dysplasia, or any combination thereof, are termed AAP (Feldman et al., 2015).

Adenomas are usually asymptomatic and are often found incidentally during colonoscopy exams performed for colon cancer screening. Occult or overt bleeding is the most typical symptom of colon polyps.

Small adenomas generally do not cause bleeding, but surface erosion on colon polyps can lead to bleeding, as histopathological data indicates (Sobin, 1985). The growth rate of each adenoma varies, but small polyps usually grow by an average of 0.5 mm per year (Bersentes et al., 1997).

Over a seven to 10 years period, the percentage of adenomas that develop into cancer is quite low— five % or less. The risk of progression is higher in advanced adenomas, which are characterized by high-grade dysplasia, a size exceeding 10 mm, or the presence of a villous component (Heitman et al., 2009).

Polyps found in the colon are classified based on their size and morphology. With regard to size, they are classified as diminutive if the diameter is 5 mm or less, small if it is between 6 and 9 mm, and large if it is 1 cm or more.

Morphologically, polyps can present as depressed, flat, sessile, or pedunculated.
Regarding their origin and types, polyps can arise from different layers of the colon. Submucosal polyps include lipomas, carcinoids, and lymphoid aggregates. On the other hand, mucosal polyps encompass adenomatous polyps, which further histopathology branch into tubular (which comprise over 80% of adenomatous polyps), tubulovillous (5–15%), villous (5–15%), and others.

Another sort of polyp is serrated, categorized into sessile serrated adenomas (SSAs) and traditional serrated adenomas (TSAs).

Additionally, non-neoplastic polyps exist, such as hyperplastic polyps, which are very common, have low malignant potential, and are more frequently found in the distal colon, and juvenile polyps, benign hamartomas commonly occurring in childhood (Chen & Vaccaro, 2018; Hsieh & Leung, 2018; Turner et al., 2018).

2.2.2.1 Etiology for Polyps

A high-fat, low-fiber diet, smoking, increasing age, being a man, and colon polyps are associated with high alcohol consumption (greater than 8 drinks per week).

Colon polyps are more common in those with colorectal cancer, intestinal polyposis, or a family history of colon polyps. Remarkably, there appears to be a correlation between inflammatory bowel disease and a lower incidence of polyps (Yoshizawa et al., 2018).

2.2.2.2 Treatment and Screening

During colonoscopy, colonic polypectomy is the standard procedure for both diagnosis and therapy. For pedunculated polyps, snare polypectomy with electrocautery is the preferred method. In contrast, for sessile polyps, mucosal resection is typically employed. According to CRC screening guidelines, colonoscopies should begin for the general population around age 50, earlier for those who are at a higher risk, and stopped if the patient's expected life expectancy is less than ten years.

There are several polyp forms that increase the risk of colon cancer: high-grade dysplasia, serrated, adenomatous, and those with more than villous histology 25%. In addition, having more than three polyps, having polyps larger than 1 cm, and having them in the proximal colon are risk factors.

Follow-up colonoscopies are advised at different intervals based on the findings:

- Every 10 years: no polyps are detected or only small hyperplastic polyps in the distal colon.
- Every five years: For tiny, non-dysplastic, sessile, serrated polyps.
- Every three years: For regular serrated adenomas, dysplasia, or large sessile serrated polyps.
- For one or two small tubular adenomas, every five to 10 years
- Every three years**:** For three to 10 adenomas.
- For more than 10 adenomas, less than three years.
- Every three years: For any adenoma that is 10 mm or more, as well as those that have high-grade dysplasia or villous characteristics.

Colectomy is recommended for resected polyps with high-risk malignancy features, such as invasion into the lower third of the submucosa, uncertain or positive resection margins, margins less than 1 mm, lymph vascular invasion, or poor differentiation, due to the high likelihood of lymph node metastasis (Jover et al., 2018; Kang & Thoufeeq, 2018).

2.2.3 Colorectal Cancer

Cancer is a disease marked by the uncontrolled growth and spread of certain cells within the body, which can originate from virtually any part of the body. Normally, cells divide, grow, and eventually die when they age or sustain damage. However, cancer disrupts this process (Brown et al., 2023).

CRC typically advances slowly and often remains symptomless until it reaches a significant size, potentially causing fecal blockage. Symptoms may include Cramps, bleeding—such as black, tarry stools, pain, or less frequently, visible blood in bowel movements. The development of most colon tumors follows a multistep process marked by histological, morphological, and genetic changes that accumulate gradually over time (Frank, 2007).

2.2.3.1 Histological and Morphological Changes

As polyps grow, they accumulate genetic and epigenetic changes that lead to histologic and cytologic dysplasia. Over time, this can progress to high-grade dysplasia, significantly increasing the risk of cancer spread. Without treatment, polyps can invade nearby tissues, penetrate the walls of the colon and rectum, and potentially metastasize to distant organs through the lymphatic and circulatory systems. Early detection and removal of precancerous polyps are essential to prevent the development and progression of colorectal cancer.

2.2.3.2 Genetic Changes

The transition from polyp to cancer involves a series of genetic and epigenetic modifications. Although inherited mutations like MLH1, MSH2, PMS2, and APC are rare (affecting approximately 5% of CRCs), they offer valuable insights. Two primary genetic pathways are associated with CRC development, linked to adenomas and SSPs.

2.2.3.2.1 Chromosomal Instability Pathway (65-70% of sporadic cancers)

Begins with APC gene mutations affecting chromosome segregation, followed by KRAS oncogene mutations impacting cell growth and survival, and ends with p53 gene loss, contributing to carcinogenesis.

2.2.3.2.2 Serrated Sessile Polyps Pathway

Initiates with BRAF gene mutations altering growth signaling and apoptosis. KRAS mutations are less common here than in adenomas and involve gene promoter region hypermethylation, silencing growth-regulating genes. Microsatellite instability (MSI) further increases genetic diversity by disrupting DNA repair, leading to additional mutations. MSI occurs in both adenomatous and serrated polyps and is associated with germline DNA mismatch repair gene mutations and sporadic MLH1 promoter region methylation (Simon, 2016).

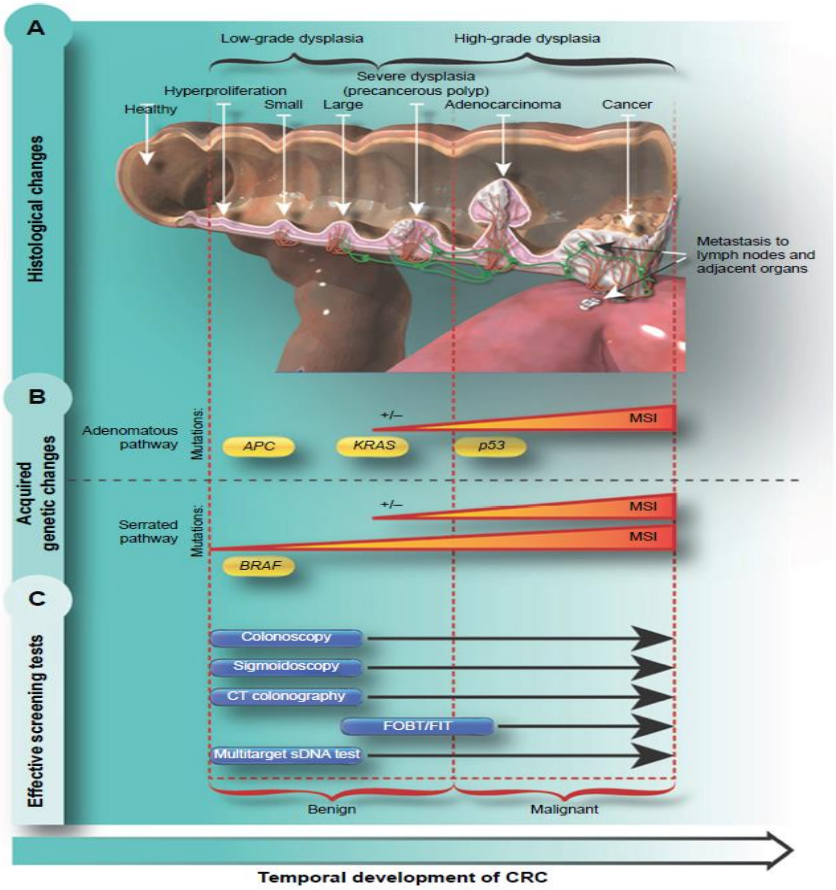


Figure 2.1: CRC creation and screening procedures (Simon, 2016).

There are two types of risk factors: modifiable and nonmodifiable: Modifiable risk factors: include lifestyle choices such as obesity, inactivity, tobacco use, and moderate-to-heavy alcohol consumption. Dietary habits, like low intake of dietary fiber, green leafy vegetables, folate, and calcium, also fall into this category. Conversely, a lower risk of CRC has been associated with increased consumption of dietary fiber, green leafy vegetables, folate, and calcium.

Nonmodifiable risk factors: include hereditary disorders like Lynch syndrome, certain racial or ethnic backgrounds, a history of inflammatory bowel disease, type 2 diabetes, and a family history of colorectal polyps or cancer.

While modifying certain risk factors can reduce the likelihood of developing CRC, it is important to note that no single change can eliminate the need for screening. Regular screening is essential for the early detection and effective management of colorectal cancer (Siegel & Jemal, 2011; Society, 2015; Tarver, 2012).

2.2.4 Epidemiology

As the second most frequent cancer in women and the third most common in males, CRC is a serious global health concern. In 2020, more than 1.9 million new cases were documented, leading to almost 935,000 deaths caused by the disease.

CRC accounts for approximately 11% of all cancer diagnoses worldwide, with incidence and mortality rates varying among different countries (Bray et al., 2018, 2024).

The incidence and mortality of CRC are particularly increasing in medium and high Human Development Index (HDI) countries that have adopted western lifestyles. Contributing factors such as obesity, sedentary lifestyle, red meat consumption, alcohol intake, and tobacco use significantly contribute to the rise in CRC cases in these regions.

Interestingly, recent studies have shown a rise in CRC incidence among younger individuals (<50 years) in several countries, including the United Kingdom (UK), India, and Australia. This contrasts with a decrease or stable incidence among older individuals (>50 years) in some countries like the USA and Israel.

Early diagnosis greatly impacts CRC survival rates, with a 5-year survival rate of 90% for early-stage diagnoses compared to 13% for later-stage diagnoses. Overall, CRC survival heavily depends on the stage at which it is diagnosed, emphasizing the importance of timely screening and detection efforts. The cumulative risk of dying from colon cancer is approximately 0.65% among men and 0.45% among women aged 0–74.

In recent years, there has been a projected 60% increase in the global burden of CRC, with estimates suggesting over 2.2 million new cases and 1.1 million deaths by 2030. This surge is attributed to economic development, particularly in low-to-medium HDI nations, and generational shifts in developed countries.

Environmental factors such as sedentary lifestyles, obesity, consumption of processed foods, alcohol, and red meat, coupled with an increase in life expectancy, are also highlighted as contributors to this rise, according to numerous research studies (Arnold et al., 2017; Bray et al., 2021; Cancer Today, n.d.; Strong et al., 2020; Wong et al., 2021).

In Palestine (West Bank), CRC is the second most common cancer, according to the latest annual report from the Ministry of Health in 2022. The incidence rate is 15.3 cases per 100,000 of the total population, accounting for 12.9% of all cancer cases. In 2019, the incidence rate was slightly lower at 14.8 cases per 100,000, representing 12.6% of cancer cases.

Cancer is the second leading cause of death in Palestine, as of 2022, with a gender distribution of 55% male and 45% female among cancer-related deaths. The total number of reported cancer deaths was 2,147. The percentages of deaths due to lung, colorectal, and breast cancers were 16.4%, 14.3%, and 11.7%, respectively (PHIC et al., 2020, 2023).

As the second greatest cause of cancer-related mortality, CRC is a serious health concern. It is the fourth most frequent cancer in the UK and accounts for 11% of all cancer-related deaths. Colorectal cancer incidence rises with age, with the average age at diagnosis being 70 years. It is more common in men compared to women.

Data from 2020 in the USA showed a lifetime risk of 4.4% for men and 4.1% for women. These statistics underscore the critical importance of implementing effective screening and early detection strategies to mitigate the impact of CRC on public health (Cianci et al., 2024).

In 2023, it is projected that there will be around 153,020 new cases of colorectal cancer in the USA. Among these cases, 106,970 tumors will be located in the colon, while 46,050 tumors will be in the rectum.

While the majority of diagnoses occur in individuals aged 65 years and older, there will be 19,550 cases (13%) in individuals younger than 50 years, with one-third occurring in individuals aged 50–64 years. Notably, around 43% of diagnoses before the age of 50—often referred to as early-onset disease—will occur in individuals aged 45–49 years, who are now recommended for screening. Furthermore, in 2023, there will be an estimated 52,550 deaths from CRC, with 3,750 (7%) of the deceased being younger than 50 years old.

The risk of colorectal CRC significantly increases with age. Between 2015 and 2019, incidence rates increased by 80% to 100% for every 5-year age group up to the age of 50. After that, they increased by 20% to 30% for those aged 55–59 and beyond. The incidence rates, however, only rise by 9% between the ages of 50 and 54 and 55 and 59 (from 60.6 to 66.1 instances per 100,000 population per year).

The advent of screening has disrupted the typical age-related pattern of identifying symptomatic CRC, which is the reason for this little increase. Screening, which was recommended to begin at age 50 until 2018, led to the detection of precancerous adenomas and prevalent cancers in asymptomatic individuals (Wolf et al., 2018).

2.2.5 Diagnosis and Screening of Colorectal Neoplasia

Colorectal polyps typically do not present noticeable symptoms and are often discovered incidentally during various examinations. Diagnostic methods for detecting colon polyps include; fecal occult blood test, fecal DNA analysis, fecal immunochemical test (FIT), colon capsule endoscopy, sigmoidoscopy, barium enema, colonoscopy, and CTC.

2.2.5.1 Guaiac-Based Fecal Occult Blood Test (gFOBT)

Guaiac test uses guaiac-impregnated paper; hemoglobin turns it blue via peroxidase reaction. In randomized studies, gFOBT for CRC detection has 31–79% sensitivity and 87–98% specificity. Sensitivity is lower for advanced adenomas than CRC.

Adenomatous polyps often don't bleed, making hemoglobin tests likely to miss them. In studies with various FOBT, detecting advanced adenoma or neoplasia has 7–20% sensitivity and 92–99% specificity (Robertson et al., 2017). gFOBT's detection for right colon lesions is lower than for left colon (Doubeni & Levin, 2018; Selby et al., 2018).

2.2.5.2 Multitarget Stool DNA Tests with Fecal Immunochemical Testing

Multitarget Stool DNA Tests, like Cologuard, combine molecular experiments for detecting mutations (MT-sDNA or FIT-DNA) with DNA (KRAS) and fecal FIT, they identify hemoglobin in feces from colorectal lesions and use gene amplification techniques with methylation biomarkers.

Effectiveness is supported by comparative studies, not randomized controlled trials for cancer screening. In a study comparing MT-sDNA and one-sided FIT in 9989 subjects, MT-sDNA showed 92% sensitivity for colorectal cancer detection, while FIT had 74%. MT-sDNA sensitivity is consistent across cancer stages and locations. Specificity is lower than FIT (87% vs. 95%) (Imperiale et al., 2004).

2.2.5.3 Fecal Immunochemical Test (FIT)

This method is intended to directly detect the presence of hemoglobin in stool samples. Unlike other tests, FIT does not necessitate dietary changes, drug restrictions, or stopping the use of aspirin or other nonsteroidal anti-inflammatory medicine. Peroxidase-active foods don't cause false positives in FIT tests.

A notable advantage of FIT is that only one fecal sample is required, as opposed to fecal occult blood testing (gFOBT), which it requires fecal sample collection for three days in a row following a particular diet. FIT demonstrates higher sensitivity for detecting colon lesions compared to gFOBT (Robertson et al., 2017; Young et al., 2015).

It is particularly effective in capturing lower gastrointestinal bleeding, although positive FIT results can also be the consequence of fast transit following significant upper gastrointestinal bleeding. In a meta-analysis review, the sensitivity of one-time FIT in detecting colorectal cancer in medium-risk populations was approximately 80% (Robertson et al., 2017).

FIT shows reduced specificity and sensitivity for advanced adenomas compared to its performance in colorectal cancer detection. Advanced adenoma detection has a sensitivity of approximately 25% to 56% and a specificity of 68% to 96%.

Despite these variations, FIT remains superior to gFOBT in detecting colorectal carcinoma and advanced adenomas, demonstrating high sensitivity and patient compliance in screening applications (Guittet et al., 2009; Lin et al., 2016; Robertson et al., 2017; Weinberg et al., 2017).

In a meta-analysis, FIT was found to outperform gFOBT in detecting colorectal cancer (RR 1.96, 95% CI 1.2–3.2) and advanced neoplasia (RR 2.28, 95% CI 1.68–3.10) (Hassan et al., 2012).

2.2.5.4 Sigmoidoscopy

less commonly used in the USA for screening, resembles colonoscopy but focuses solely on examining the distal half of the colon. Sedation isn't required, and bowel preparation involves an enema on the day of the examination. It exhibits a sensitivity of around 95% for CRC in the examined portion of the colon and 70% sensitivity for advanced adenomas (10 mm or larger).

If lesions are discovered in the distal colon, a follow-up colonoscopy is necessary, as it may reveal additional lesions in the proximal colon. Sigmoidoscopy has shown a significant 60% reduction in mortality from distal colon CRCs, but it has limited impact on reducing morbidity and mortality from proximal CRC due to the lack of screening in this area.

Current guidelines recommend pairing sigmoidoscopy with high-sensitivity FOBT and repeating the procedure every five years for asymptomatic individuals with no history of colon polyps. Like colonoscopy, sigmoidoscopy can detect and remove both cancerous and precancerous lesions, albeit limited to the distal colon (Simon, 2016).

2.2.5.5 Colon Capsule Endoscopy

Colon capsule endoscopy (CCE) is emerging as a promising alternative to colonoscopy, offering a noninvasive, low-risk, and at-home testing option without the need for

sedation. CCE provides a comprehensive view of the entire colon, with performance matching that of colonoscopy in several trials.

The sensitivity for detecting polyps larger than 6mm and 10mm has notably increased with the second-generation (CCE II) colon capsules compared to the first-generation (CCE I).

Among 582 studies, 13 were included, covering 2,485 patients. Eight studies used CCE after a positive FIT, while five used it for primary screening. CCE's polyp detection rate ranged from 24% to 74%. For polyps larger than 6mm, sensitivity ranged from 79% to 96%, with specificity ranging from 66% to 97%. For polyps 10mm or larger, sensitivity ranged from 84% to 97%, surpassing that of CTC.

Completed CCEs achieved a 93% colorectal cancer detection rate (25 out of 27 cases). Bowel preparation was adequate in 70% to 92% of exams, and completion rates varied from 57% to 92% based on the booster used. No complications related to CCE were reported (Vuik et al., 2021).

2.2.5.6 Barium Enema

Detecting polyps with barium enema depends on the size of the polyp. It has a false positivity rate of 5–10% due to inadequate colon cleansing and a false negativity rate of 10% due to factors such as diverticula, redundant bowel, and weak mucosal coating. Barium enema is not routinely used as a screening test. According to data from the National Polyp Study Group, the detection rates for polyps less than 6mm, 6–10mm, and larger than 10mm are 32%, 53%, and 48%, respectively (Winawer et al., 2000).

2.2.5.7 Colonoscopy

Is a procedure conducted using a fiber-optic flexible colonoscope, offering visualization of the entire colon from the rectum to the terminal ileum, and some parts of the ileum. According to a meta-analysis involving six studies, colonoscopy screening has been shown to reduce the risk of colorectal cancer incidence and death by 40–60% compared to sigmoidoscopy screening (Brenner et al., 2014).

Observational studies have demonstrated that colonoscopy significantly lowers the incidence of colorectal cancer. In a population-based study involving 94,959 individuals aged 55–64, those who underwent colonoscopy screening exhibited a 40% screening rate. In this screened population, colorectal cancer was detected in 50%, adenoma in 31%, and high-risk adenoma in 10% (Bretthauer et al., 2016).

A systematic review study found that colonoscopy sensitivity ranged from 75% to 93% in detecting adenomatous polyps 6 mm or larger (Lin et al., 2016).

Another review study involving 465 patients with prior tandem colonoscopies reported miss rates of polyps in various size categories: 22% for any size, 2% for adenomas ≥10 mm, 13% for 5–10 mm, and 25% for <5 mm (Van Rijn et al., 2006).

Colonoscopy is considered the gold standard for colorectal cancer screening, although it has some limitations. In approximately 10% of cases, the cecum cannot be reached, and the procedure typically requires sedation. It is also more costly than other screening methods like FOBT, FIT, and sigmoidoscopy. Additionally, polyps or neoplasms located behind flexures or folds may be overlooked (Rex, 2006).

To ensure a high-quality colonoscopy, proper bowel cleansing, examination until the cecum, and a withdrawal time of 6 minutes or more are recommended.

While various imaging modalities have been introduced to enhance colonoscopy's ability to capture small polyps, chromoendoscopy (dye-spraying the colonic mucosa) has shown a slight superiority in detecting adenomas compared to conventional colonoscopy.

However, its limited adoption is attributed to the time-consuming nature of the procedure, higher cost, and a higher likelihood of detecting non-neoplastic polyps.

According to a meta-analysis of randomized studies, high-resolution white light using narrow-band imaging NBI did not significantly improve adenoma detection by the colonoscope (Pasha et al., 2012).

Consequently, advanced imaging techniques are not universally recommended for the screening of the population with moderate risk.

2.2.5.8 Computed Tomography Colonography

CTC involves using thin-section CT data to create two- and three-dimensional images of the intestinal mucosa. After bowel preparation, intravenous glucagon can aid bowel relaxation, and air or carbon dioxide is administered through a rectal catheter. Imaging is conducted during a 32-second breath-holding sequence, and no sedation is required.

Although there are no controlled studies on CTC's impact on CRC incidence or mortality, seven studies indicate a sensitivity of 67% to 94% and specificity of 96% to 98% for detecting colorectal cancer and adenomas 10 mm or larger (Lin et al., 2016).

In symptomatic patients from high-prevalence societies, the sensitivity rates for polyp detection are 29% to 59% for small polyps, 47% to 82% for medium-sized polyps, and 63% to 92% for large polyps (Kim et al., 2007).

The Multicenter Study reports a 90% sensitivity for detecting adenomas 10 mm or larger and 78% for adenomas sized 6 to 9 mm. However, CTC's detection rate for polyps smaller than 5 mm is notably low based on available studies (Johnson et al., 2008).

This study aims to evaluate the reliability of CTC in detecting colorectal neoplasia by comparing it with the gold standard, colonoscopy. The objectives include determining the accuracy and sensitivity of CTC, identifying issues that contribute to poor results, and developing solutions to address these challenges. Additionally, the study seeks to explore alternative methods to colonoscopy and incorporate a CTC scan protocol for the early detection of colorectal lesions.

2.2.6 Colonoscopy

Colonoscopy is a diagnostic and therapeutic procedure for examining and treating the entire colon, from anus to cecum, using flexible instruments with light and a camera. It's minimally invasive, safe with low complications when performed by experienced teams. Colonoscopy is more specific in detecting colon polyps and malignancies compared to other methods. It can be done in endoscopy offices due to its simplicity.
Modern colonoscopy devices and improved imaging have increased life expectancy through preventive and therapeutic measures.

The procedure examines the colonic mucosa, including the terminal ileum. Understanding colon anatomy is essential: cecum, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, sigmoid colon, rectum, anal canal, and anus (Messmann, 2011; Waye et al., 2008).

Colonoscopy is a widely utilized method for diagnosing and treating gastrointestinal diseases. It remains the "gold standard" for assessing the large intestine. With an increasing number of intestinal disease cases, there's a growing demand for colonoscopy examinations.

Continuous advancements in bowel cleansing methods and administration patterns are being developed. Diagnostic and interventional colonoscopies carry potential adverse events, including severe complications that can endanger patient health and life. Adequate bowel cleansing is crucial for successful endoscopic procedures. However, in an aging population, patients undergoing these procedures often have various comorbidities. CS preparation can be lengthy, spanning several hours and with unpredictable individual experiences. Macrogols, particularly polyethylene glycol (PEG), are commonly used for bowel preparation before diagnostic endoscopic (Latos et al., 2022).

Colonoscopy is a retrograde examination, providing insight into the inner surface of the colon but unable to identify lesions within the colon wall. Characteristics of mucosal lesions in colon cancer can be identified, but other imaging methods like endoscopic ultrasound, magnetic resonance imaging (MRI), or CT are needed for detailed information on layers and serosal invasion (Hunt & Waye, 1981; Tanaka et al., 2001).

2.2.6.1 Colonoscopy Indications and Contraindications

Colonoscopy is a sophisticated, minimally invasive procedure that demands expertise because of its expense and possible complications. As a result, it should be selectively performed on patients (Al-Shamali et al., 2001).

Indications for colonoscopy encompass various conditions including lower gastrointestinal bleeding, chronic constipation, uncomplicated diarrhea, iron deficiency anemia, lower abdominal pain, assessment of existing Crohn’s disease and ulcerative colitis, screening for colorectal cancer in individuals with inflammatory bowel conditions,

post-polypectomy and post-colorectal cancer surgery follow-ups, colorectal cancer screening, colonic masses, intraluminal colonic abnormalities, and unexplained weight loss, among others.

There are two types for contraindications: relative and absolute. intestinal blockage (complete or high-grade), fulminant colitis, patient refusal, acute peritonitis, toxic megacolon, intestinal perforation, and patients who can give consent but are uncooperative during the surgery are all absolute contraindications. Relative contraindications consist of bleeding disorders, thrombocytopenia, platelet dysfunction, neutropenia, previous bowel surgery, patients at risk of bowel perforation (Ehlers-Danlos syndrome, Marfan syndrome, etc.), acute diverticulitis, history of cardiac infarction, pulmonary embolism, very large abdominal aortic aneurysm, pregnancy (second or third trimester), and hemodynamic instability (Engin, 2020).

2.2.6.2 Colonoscopy Complications

Complications arising from the colonoscopy procedure may be attributed either directly to the process itself or to other systemic factors within our body, such as hypertension or cardiac issues. These complications encompass issues like perforation linked to the colonoscopy, splenic trauma, bacteremia, severe abdominal distension, bleeding, missed adenoma, and incomplete removal of neoplasia, which may manifest following the completion of the procedure (Engin, 2020).

2.2.6.3 Anesthesia in Colonoscopy

In the past decade, the demand for anesthesia has grown in proportion to the increasing number and complexity of endoscopic procedures. Anesthesiologists are facing a substantial burden due to factors such as an aging population, prevalent comorbidities, and the imperative for effective, reliable, and timely patient care (Bhavani & Abdelmalak, 2019).

Historically, as anesthesia was not required for most gastrointestinal interventions, endoscopy rooms were not initially designed to accommodate anesthesia needs (Bader & Pothier, 2009).

However, in developed countries, a significant majority of lower gastrointestinal interventions now involve the administration of anesthesia (Trummel et al., 2017). Colonoscopy, a prominent lower gastrointestinal procedure, can elicit physical and emotional challenges such as fear, anxiety, and embarrassment (Trevisani et al., 2014).

While diagnostic colonoscopy can be performed without sedation, opting for sedation during colonoscopy yields superior results, enhances patient comfort, and increases satisfaction among endoscopists regarding diagnostic quality (McQuaid & Laine, 2008).

To ensure a secure, comfortable, and technically successful endoscopic intervention, it is crucial to optimize the level of sedation. Additionally, a comprehensive understanding of the pharmacological properties of the sedative agents used is essential for titrating the sedation level to achieve the desired outcome (Waring et al., 2003).

2.2.6.4 Pre-anesthesia Evaluation Before Colonoscopy

In the assessment before sedation or anesthesia, it is essential to investigate the prescription products used by the patient, including a thorough exploration of allergies. It is important to review detailed information about previous hospitalizations, surgeries, and any negative experiences with sedation or anesthesia. Even when airway instrumentation is not anticipated, a comprehensive examination of the airway, heart, lungs, and nervous system is recommended for all patients.

This preoperative evaluation plays a crucial role in resolving pre-interventional medical problems and reducing the likelihood of cancellations (Bhavani, 2016). Before administering sedation or anesthesia, a physical examination should be conducted, which includes checking vital signs, listening to the heart and lungs, and assessing the patient's level of consciousness and airway anatomy.

This assessment is crucial for developing an appropriate anesthesia plan. While some aspects of preoperative assessment are standardized, others can be personalized based on the patient, timing of the assessment, and the nature and location of the intervention (Weiss & Fleisher, 2014).

During the preoperative period, obtaining informed consent from patients is essential, the consent should provide information regarding the sedation process, alternative options, potential risks, benefits, and limitations. This ensures that patients are well-informed and have given consent before undergoing the sedation or anesthesia procedure (Zuckerman et al., 2007).

Anesthesia gets trickier with more comorbidities, leading to increased complications. So, anesthesia consultation is crucial for certain patients (Chang & Urman, 2016).

2.2.6.5 Complications Related to Anesthesia

During a colonoscopy, sedation may increase morbidity and, in rare cases, fatality. The kind of sedative, dosage, mode of administration, patient age, and coexisting conditions all affect the risks. Hypoxia, hypoventilation, arrhythmias, and hemodynamic issues may occur.

Deeper sedation aids completion but raises aspiration and pneumonia risks. Aspiration incidence during colonoscopy is 0.10-0.14%, possibly higher with propofol. Be ready for complications like vagal reactions, bleeding, and colon lacerations.

Airway obstruction, common in deep sedation, may go unnoticed in darkened endoscopy units. Outside the operating room, there should be a defibrillator and medication cart ready for cardiopulmonary resuscitation. The position and usage of the defibrillator must be known by the anesthesia personnel (Engin, 2020).

2.2.7 Computed Tomography

CT has been a vital imaging tool for over sixty years. In 1972, the first head CT scanner was released, with each pair of slices taking more than 4 minutes to scan and over 1 minute for reconstruction.

Although this process may seem inefficient by modern standards, it was groundbreaking at the time, in 1979, Allan Cormack and Godfrey Hounsfield received the Nobel Prize in Medicine in recognition of their novel research. An X-ray tube is at the core of a CT scanner. In this tube, thermionic emission occurs when a heated tungsten filament releases electrons.

A potential difference causes these released electrons, which have a negative charge, to accelerate in the direction of a positively charged copper anode. This entire process occurs within an evacuated glass housing. The vacuum inside the housing is crucial as it prevents the electrons from interacting with materials other than the tungsten target. ensuring the accuracy of the imaging process.

The attenuation contributions from each pixel along the same line of response are added up to determine the overall attenuation along the line of response:

$$I_x = I_0 \times e^{-(\mu 1+\mu 2+\mu 3+\cdots+\mu n)\times d}$$

This is expressed as a formula where d represents the pixel dimension and μ1 to μn are the linear attenuation coefficients of each pixel.

Each pixel on a CT image represents the average attenuation qualities of the tissue in that voxel since CT imaging adds a third dimension, the slice thickness. A view, or projection, is a group of rays that travel through the patient in the same direction. About 800 rays at 1000 distinct projection angles may be used in a single axial CT scan, with a slice dimension of 512 × 512 pixels as the typical outcome.

The capacity to reconstruct several projections into cross-sectional images is a significant benefit of CT imaging. Johann Radon's 1917 discovery that an endless number of two-dimensional projections may be used to create the image of a three-dimensional object laid the mathematical groundwork for this method.

The advancement of faster computer processing was pivotal in enabling the technique and the familiar images seen in CT scans today. This transition from incremental single-slice acquisition to spiral CT, made possible by slip ring technology, allowed for the acquisition of single-breath hold images, albeit still lasting 15–20 seconds (Halligan & Fenlon, 1999).

Continued advancements in CT technology have led to the development of multi-detector scanners capable of scanning isotropic sub-millimeter slices within seconds, followed by rapid processing and display of the images. With these advancements, the entire colon can now be scanned within a single breath hold lasting under 10 seconds. This not only improves patient cooperation but also enhances image quality compared to earlier single or four-slice scanners (Laghi, 2014; Yee et al., 2013).

Modern scanners offer a crucial opportunity to significantly reduce the radiation dose received by patients during CTC by up to 50%. This reduction is made possible through the implementation of techniques such as dose modulation and iterative reconstruction (Laghi, 2014; Yoon et al., 2012).

David Vining first presented CTC as a proof of concept in 1994. He performed a 50-second scan using a single-detector CT scanner to obtain a volumetric dataset of an inflated colon. Subsequently, Vining reconstructed this dataset into a three-dimensional fly-through movie, a process that required 8 hours of processing time on a Silicon Graphics Crimson workstation (Vining, 1994).

Over time, from an experimental imaging technique, CTC has developed into a promising approach for polyp and cancer detection, particularly in patients unable to have a colonoscopy. Today, it has become a well-established and publicly recognized option for colorectal cancer screening (Bibbins-Domingo et al., 2016; Levin et al., 2008).

Accurate interpretation of CTC demands additional specialized training. It's crucial for all team members to undergo appropriate training tailored to their roles, under the guidance of a radiologist with substantial expertise in CTC. preserving quality control in all areas of the service, such as colon distension, patient comfort, and reporting precision, is essential for enhancing performance and patient outcomes.

However, implementing such measures carries implications for training and workforce requirements within the hospital, inevitably incurring financial costs for the institution. It's important to note that while training is essential, it alone does not guarantee competency (The British Society of Gastrointestinal and Abdominal Radiology (BSGAR) et al., 2021; BSGAR and The Royal College of Radiologists (RCR), 2014).

Training, coupled with structured competencies, plays a vital role in narrowing performance gaps among different institutions. Allowing a skilled reader to review images during scanning provides an opportunity to adjust techniques for ideal distension and modify the patient's route as necessary during the examination. For instance, this flexibility enables staging scans to be performed promptly when colorectal cancer is identified, this optimization enhances efficiency and ensures that patients receive the best possible experience and outcome (BSGAR et al., 2021).

Radiographers should receive comprehensive information and training covering all aspects of CTC, including patient-centered communication, obtaining patient consent, optimizing distension, luminal navigation, and problem-solving. Initial clinical assessment of obtained images should be prioritized.

Radiographers can then evaluate the images critically while the patient is still on the scanner and decide what more imaging is needed, like injecting contrast or doing a decubitus scan if the first scans are considered insufficient.

In facilities where radiographers are entrusted with decision-making responsibilities, it is crucial to have local policies and protocols that support this role, along with providing appropriate training and feedback. Accurate interpretation of CTC necessitates additional focused training. The data acquired can be displayed in various formats, including Multiplanar reconstructions (coronal, sagittal, and axial).

Three-dimensional endoluminal fly-through, where the software generates a centerline throughout the colon lumen, mimicking a colonoscopy view, displayed as a bisected tube 'filet' view (Virtual dissection).

A primary two-dimensional or primary three-Dimensional read can be used to examine images obtained from CTC. As of right now, opinions differ about whether the strategy is better. Nonetheless, the three-dimensional review has been shown to be more sensitive in identifying polyps in patients undergoing screening.

Software algorithms for computer-aided detection (CAD) are frequently found in post-processing CTC software packages. To minimize interobserver variation and interpretation time, it is intended to detect potential polyps or malignancies and flag these results for the reader to evaluate. Over the years, technical developments have enhanced CAD performance.

However, its effectiveness may depend on the quality of scan data obtained. Despite this, CAD has been shown to significantly impact polyp identification, particularly benefiting inexperienced CTC readers. Nevertheless, poor bowel preparation can lead to false-positive CAD findings, causing some experienced readers to refrain from using it (Bortz et al., 2023).

2.2.7.1 Patient preparation

2.2.7.1.1 Diet

The initial step in achieving a clean colon involves dietary modifications. Patients are instructed to follow a fiber-restricted diet to minimize solid feces that can make it difficult to spot polyps on CT images. This typically includes avoiding fiber-containing foods for up to 72 hours before the examination (Chang & Kim, 2018).

During the clear fluids diet preceding the examination, patients are encouraged to consume abundant fluids, especially the day before the procedure. Bowel catharsis is aided by adequate fluid intake, particularly when combined with osmotic agents such as magnesium citrate. Moreover, drinking enough of fluids counteracts the potential for considerable fluid loss throughout osmotic bowel prep. It is recommended that patients consume approximately 5–8 oz of fluid per waking hour on the day before the CTC (Holte et al., 2004).

In prospective CTC study induce on 1446 outpatient, found that the lack of dietary restrictions before the exam, did not impact the quality of CTC preparation, and good patient compliance suggests that this approach could potentially enhance participation rates in CRC screening programs (Rengo et al., 2023).

According to the European Society of Gastrointestinal and Abdominal Radiology (ESGAR) guidelines, administering the use of a cathartic agent and the application of dietary restriction and fecal tagging are necessary procedures before CTC.

Although the cathartic program has been the subject of numerous research, little is known about the impact of food restriction. As of right now, opinions differ widely over the details of the food restriction plan. Guidelines suggest following a low-residual diet for 24 hours or more before the examination (Rengo et al., 2023).

2.2.7.1.2 Colonic Preparation

Patients' reluctance to undergo stool cleansing is a major barrier to attaining effective CRC screening, whether using OC or CTC. With same-day polypectomy, cathartic bowel preparation is required for both CTC and optical OC.

Various bowel preparations are available, and most are effective. However, there is no standard protocol as opinions differ on the best preparation method.

Upon the introduction of CTC in 1994, Sodium phosphate (NaP) was initially the recommended agent, and patients generally tolerated its use well. According to a 2007 study, 90 mL or 45 mL of sodium phosphate could be used to effectively clean the colon. Then Magnesium citrate continues to be the primary cathartic agent used for CTC.

The standard regimen typically involves the consumption of two 296 mL bottles of magnesium citrate, whereas only one bottle of sodium phosphate is typically required. Magnesium citrate is preferred due to its lower likelihood of causing significant electrolyte imbalances compared to sodium phosphate. Adequate fluid intake is crucial to prevent dehydration when using magnesium citrate.

Bowel catharsis is essential for complete colon lavage. There are two major categories of cathartic agents: "wet" or high-volume (iso-osmolar cathartics), and "dry" or low-volume (hyperosmolar cathartics) (Bortz et al., 2023).

The traditional "wet" lavage techniques employ 4- to 6-liter regimens of polyethylene glycol (PEG: Klean-Prep), marketed under a variety of commercial names, including Gavilyte GoLytely, Nulytely, and Colyte. However, bowel preparation is considered the most uncomfortable part of getting ready for a colonoscopy or CT scan since these high-volume procedures are often difficult for patients to tolerate.

More recently, relatively decreased 2-liter volume "wet" preps have been developed and have shown to be better tolerated by patients while still effectively cleansing the colon, especially when combined with adjunct agents such as bisacodyl (Beebe et al., 2007; Parente et al., 2015; Téllez-Ávila et al., 2014).

Polyethylene glycol Bowel cleansing agents function as osmolar agents by causing elimination and raising the water within feces. However, A lot of people dislike the bowel-cleansing agents that are currently on the market. Thus, the goal of current research is to identify a cathartic medication that will both help patients accept it and lower the amount of residual fluid in their bowels. A new formulation known as Suprep (OSS) was released into the OC market in 2010 in response to this demand.

OSS is an oral sulfate (low-volume) solution used for bowel preparation. 17.5 g of sodium sulfate, 1.6 g of magnesium sulfate, 3.1 g of potassium sulfate, and flavoring ingredients are included in each dose of OSS.

The aqueous liquid is packaged in a 177 mL plastic bottle. Since OSS does not change the electrolyte balance and sulphate is a weakly absorbed anion, the suggested protocol for preparing for an OC is to take two × 177 mL bottles of OSS in split doses to sufficiently clear the colon for OC tests.

In a trial conducted by Bannas et al., five different cathartic regimes were employed:

- A single dose of mL NaP, 45 ml.
- Two doses of NaP (45 mL each) administered 3 hours apart.
- Two doses of MgC, each 296 mL, taken 3 hours apart.
- Four liters of PEG divided into 16 portions of 237 mL, consumed every 10 minutes.
- The OSS purgation regimen involved a single 177 mL bottle of oral sulfate solution diluted with 296 mL of water before consumption.

The night before the CTC examination, all patients received 250 mL of Readi-Cat 2 and 60 mL of Gastrografin to tag any leftover feces or fluid. The amount and attenuation of remaining colonic fluid were measured by the authors using an automated quality assurance software tool.

The results of Bannas et al. 2014 indicated that the Suprep regimen at the time was better than any other cathartic medications that had been utilized in the past for CTC bowel preparation. This resulted in less residual fluid compared to the other cathartic agents used, and there was an increase in the fluid attenuation value (Bannas et al., 2015; Bortz et al., 2023).

"Dry" cathartics, on the other hand, involve low-volume hyperosmolar agents, decreasing the amount of residue fluid in the intestinal lumen, increasing patient tolerance, and improving the view of the colonic wall and gas distention. Examples include magnesium citrate and sodium picosulfate. While these options are generally well-tolerated and effective, there is a potential increased risk of hyperosmolar preparations in patients prone to renal failure.

As a result, "wet" preparations are often preferred over "dry" ones in these patient groups. Sodium phosphate, a "dry" cathartic that was initially popular, has since been removed from the USA market because of its link to metabolic disturbances and renal failure in certain individuals. However, there is unlikely to be a significant difference in cleansing ability between various hyperosmolar agents (FDA, 2024; Heher et al., 2008; Macari et al., 2001).

2.2.7.1.3 Tagging of Feces and Fluids

Oral tagging agents are used to enhance the visibility of any remaining endoluminal fluid and stool particles. Colonic polyps that are submerged cannot be differentiated from nearby untagged colonic fluid, as their attenuation is too similar to be detected by CT. However, by opacifying the residual fluid through the use of either iodinated and/or barium contrast agents, submerged soft tissue attenuation polyps can be better visualized (Callstrom et al., 2001; Fletcher et al., 2000; Iannaccone et al., 2004).

Tagging agents can lessen the need for dual patient positioning and the use of lower volume cathartic agents by improving polyp visibility, regardless of the position of any remaining endoluminal fluid. These agents integrate into residual stool particles, increasing internal attenuation and making it easier to distinguish between a stool and polyps.

Tagging agents are primarily divided into two categories: barium contrast agents and iodinated contrast agents. Different regimens using iodine alone or in combination with barium are generally initiated the day before the CTC exam. Iodinated contrast agents are regarded as more effective for tagging residual fluid, though they also have some stool tagging capabilities, while barium is more effective in tagging stool than fluid. A combination regimen of iodine and barium ensures adequate tagging of both fluid and residual stool.

More recently, tagging agents have been recognized as essential for detecting flat polyps by tagging the adherent mucin coat of these lesions to aid in their detection (Kim et al., 2014, 2016). In addition to enhancing the sensitivity of CTC, fecal tagging reduces the need for a completely dry bowel, as is typically required in endoscopy procedures (Lefere et al., 2002).

If enough distension is achieved together with minimum processing of fecal waste, pathology within the tagged fluid can be easily identified. An optimal residual fluid value of 900–1100 Hounsfield Units (HU) enhances the reader's confidence in distinguishing potential pathology (around 200 HU) from adhered fecal matter (around 900 HU) (Scalise et al., 2016; Utano et al., 2019; Wilson & Thompson, 2020).

Preparations and protocols for CTC are still non-standardized and can differ throughout hospitals based on physician preferences, pharmacy availability, and specific contracts. Studies show that when paired with a successful 24-hour low-residue diet and sodium amidotrizoate 100 mg/meglumine amidotrizoate 660 mg (Gastrografin) used as a laxative and fecal tagging agent, highly diagnostic pictures can be obtained.

Gastrografin high osmolality draws fluid into the intestinal lumen, raising the residual fluid's density. Further research suggests that employing Patients always tolerate Gastrografin better when given in a split bolus regimen of 75 mL/25 mL 24 hours before the test, which improves colonic lavage. However, this study involved 100 patients with a mean age of 76 years (Bayer, 2023; Lung et al., 2014; Wilson & Thompson, 2020).

2.2.7.1.3.1 Barium Contrast

Is mostly utilized for stool marking and has a very low chance of allergy because it is an inert element. A single dosage or several divided doses given 24 to 48 hours before the exam, ranging in volume from five to 24 g of barium sulfate in concentrations from (2% -40% weight in relation to volume), are typical amounts consumed.

Giving barium orally before diatrizoate iodinated contrast is crucial since giving it afterward may result in a diffuse thin layer of contrast coating throughout the colon. Compared to 40% barium, two percent barium produces fewer beam-hardening artifacts and does not block ports during same-day colonoscopies.

However, tagging can lead to imaging-related artifacts, such as beam-hardening artifacts, particularly at lower peak kilovoltage (kVp) scanner settings. These artifacts, often referred to as "streak artifacts," can interfere with the visualization of nearby extracolonic structures.

A type of streak artifact can occur when tagged residual fluid actively spills between haustral folds during a helical scan, leading to the appearance of the "dense waterfall" sign (Boyce et al., 2012).

Barium does not stick to the colon wall; instead, it covers polyp surfaces, making them more noticeable and facilitating diagnosis. This can potentially lower the false-positive rate in CTC. Both Omnipaque and Gastrografin cause residual fluid to appear white, assisting in the two-dimensional assessment of submerged polyps. Due to its hypertonic nature, Gastrografin also breaks down stool adhered to the bowel wall, leading to a secondary catharsis (Kim et al., 2014).

2.2.7.1.3.2 Iodinated Contrast

Tagging options include hypertonic agents like diatrizoate sodium (traded as Gastroview and Gastrografin), and diatrizoate dimeglumine and as well as less hypertonic agents such as iopromide (Ultravist), iohexol (Omnipaque), and iodixanol (Visipaque). Diatrizoate sodium and diatrizoate dimeglumine also possess emulsification and detergent properties that help mix with and loosen adherent stool from the colonic wall.

However, their hypertonic nature can cause diarrhea and cramping. These symptoms may be partially mitigated by using less hypertonic agents, which do not draw as much fluid into the bowel lumen.

Diatrizoate often has a less pleasant flavor compared to less hypertonic agents. This issue can be somewhat alleviated by refrigerating the solution and/or mixing it with clear sodas or juices. There is a theoretical danger of anaphylactoid reaction with all of these water-soluble contrast agents because they are or have features with iodinated intravenous (IV) contrast; nevertheless, the risk is much reduced when administered orally than when administered intravenously.

In certain medical facilities, patients who would otherwise be eligible for anaphylactic prophylaxis for IV contrast may only receive barium-only tagging. In combined experiences involving over 13,000 individuals over nearly a decade and a half, there have been no reported anaphylactoid reactions to the orally ingested iodine tagging agent used in the protocol. (Boyce et al., 2012).

The non-ionic contrast medium Omnipaque is regarded as safer than Gastrografin. A comparative study between these two contrast agents revealed that patients found the taste of Gastrografin to be unpleasant. This preference for Omnipaque over Gastrografin may contribute to better patient compliance and acceptance of the bowel preparation regimen (Johnson et al., 2016).

The main contraindication for the use of Gastrografin is a known hypersensitivity to iodine. Asthmatic patients should also exercise caution, as they may experience bronchospasm. Additionally, patients with hyperthyroidism should avoid Gastrografin due to its iodine content, which could exacerbate their condition

The day prior to the scheduled examination, patients are required to adhere to a 24-hour liquid diet. Bowel preparation involves a standard dry protocol.

The example procedure entails: ingesting 2 × 5 mg bisacodyl (Dulcolax) tablets with one glass (8 ounces/234 mL) of clear fluid at 11:00 am, consuming a 296 mL solution of magnesium citrate at 14:00 pm, followed by another 296 mL dose at 17:00 pm on the day preceding the study, intake of a tagging agent, specifically 250 mL of 2.1% w/v Readi-Cat, at 17:00 pm, which helps to highlight any remaining stool, and ingestion of 50 cc iohexol (Omnipaque) at 20:00 pm to highlight residual fluid by staining it white (Bortz & Munro, 2018).

2.2.7.1.4 Bowel Distension

Besides ensuring a well-prepared colon, another essential aspect of conducting high-quality CTC is achieving adequate distension of the colon. If a segment of the colon cannot be sufficiently distended during any of the scanning positions in CTC, it becomes impossible to evaluate that segment for polyps or masses. Therefore, efforts should be made to optimize colonic distension during CTC to prevent unnecessary optical colonoscopy for completion evaluation of a collapsed yet normal colonic segment (Burling et al., 2006; Chang & Kim, 2018).

During CTC studies, two methods are commonly utilized for colon insufflation: manually with a handheld device (air room) or automatically by the use of an insufflator with pressure control by Carbon dioxide (CO_2).

The advantage of CO_2 over room air lies in its rapid absorption from the colon through normal breathing, with absorption rates approximately 150 times faster than room air which mainly contains oxygen and nitrogen. As a result, patients experience fewer cramps during and after the CTC study when CO_2 is used (Bortz, 2014; RANZCR, 2013; Singh et al., 2012).

Manual insufflation requires a handheld air-bulb insufflator, and while both room air and CO_2 can be used for colonic distention, room air is free whereas there are costs associated with CO_2 usage. Each puff of a handheld device introduces approximately 40 cc of air, meaning at least 50 puffs are necessary to introduce two liters of air. However, the pressure at which the air is introduced remains unknown (Bortz et al., 2023).

The Manual inflation with room air may be utilized when an automated insufflator is unavailable or in cases where more than 25–35 mmHg of endoluminal pressure is required for adequate colonic distention (Bellini et al., 2014; Pickhardt, 2006; Sosna et al., 2006).

Automated carbon dioxide insufflation is preferred for colonic insufflation as studies have consistently shown that it results in more consistent and higher volume colonic distention compared to manual insufflation with room air (Burling et al., 2006; Chang & Kim, 2018).

During the examination and under medical supervision the insufflation of four liters of CO_2 at low pressure (20 mmHg). Tumors blocking the colon, tumors accompanied by an abscess or fistula, recent colorectal surgery, and acute colonic diseases including diverticulitis are contraindications to insufflation.

Laxative colonic preparations may not be well tolerated, which restricts their usage in situations where a tumor is too big for the colonoscope to navigate. If there are no contraindications, there is a 0.001% chance of perforation (Cadi et al., 2022).

The dial on an automated CO_2 insufflator is continuously monitored. CO_2 is introduced into the colon gently until 1 liter has been insufflated. Then, the pressure is gradually increased to 20 mmHg or higher if needed, typically up to a maximum of 35 mmHg in most CO_2 insufflators, although some can handle pressures exceeding 35 mmHg.

The key is to increase the pressure gradually. Studies have demonstrated that using a constant pressure infusion of CO_2 is effective in achieving colon distension, both in stenosing and non-stenosing carcinomas (Kim et al., 2008).

The newly automated insufflator introduced VMX-1020A insufflator from Vimap Technologies features an innovative capability to warm the CO_2 during colonic insufflation.

This product offers temperature settings ranging from 30 to 47 °C, which can be adjusted either as a constant setting or according to specific requirements. According to Nicolas Costovici from Vimap Technologies, the manufacturer included this warming option to help relax the colon wall (Farley et al., 2004).

While colonic perforation risk with CTC is rare, instead of using automated carbon dioxide insufflation, the majority of documented examples use manual insufflation using room air. Sufficient intestinal distention is essential, particularly when doing CTC scans on patients in various positions.

At all scan points, automated carbon dioxide insufflation guarantees reproducible distention when the pressure cutoff is kept between 20 and 30 mmHg. To ensure adequate distention, it is recommended to delay the initial scan until volume measurements are close to 4 liters. This will allow the colon to fill and relax.

After the initial scan, re-initiating insufflation before obtaining the second set of scout topograms may enhance patient comfort. In the case of room air bulb inflation, it is often necessary to repeat the process between changes in patient position to sustain sufficient colonic distension.

Two patient positions are used by CTC during scanning, which facilitates the redistribution of gas and residual fluid to different segments or dependent positions inside the colon. This maximizes the visualization of unsubmerged colonic mucosa during the interpretation of three-dimensional and two-dimensional CTC images (Pickhardt et al., 2014).

2.2.7.2 Intravenous Contrast

IV contrast is generally not recommended for asymptomatic persons in the UK. Research shows that IV contrast improves the detection of medium and large polyps but has no discernible effect on small polyp detection. However, even with IV contrast, very flat lesions can still be overlooked.

Yau et al. argue that IV contrast doesn't improve the detection rate of clinically significant findings in symptomatic patients but may increase the identification of incidental findings such as liver lesions, leading to further appointments and investigations like ultrasound or MRI (BSGAR et al., 2021; Burling & Standards, 2010; Morrin et al., 2000; Yau et al., 2014).

Computed Tomography Colonography Angiography (CTC-A), does not serve as a substitute for injected thoraco-abdomino-pelvic CT (TAP-CT) or colonoscopy. However, when used in conjunction with these pre-operative assessments prior to colectomy for cancer, it has the potential to enhance surgical planning and improve outcomes. This is especially beneficial for patients with thick mesenteries, dolichocolon, or tumors that are difficult to navigate during colonoscopy (Cadi et al., 2022).

Extracolonic findings (ECFs) may be detected on CTC scans even in the absence of IV contrast, revealing both subtle pathology with or without contrast. However, when colorectal cancer is suspected on CTC images, IV contrast should be used for staging if specific criteria are met.

IV contrast aids in identifying the invasion of pericolic fat planes and nearby organs, as well as detecting metastases in regions such as the lungs or liver. Different institutions have varying protocols for IV contrast administration, so it's recommended to follow institutional policies, ensuring that the abdomen is scanned during the portal venous phase.

Some studies have explored using arterial phased staging during CTC as a preoperative assessment to aid in surgical planning for colorectal cancer detected during OC, guiding surgeons in identifying vessels requiring resection (BSGAR et al., 2021; Cadi et al., 2022; Hiroishi et al., 2018; Morrin et al., 2000).

When deciding on IV contrast usage in a CTC service, the lead CTC radiologist should consider factors such as cost, risks associated with contrast use, and the clinical indication for the examination, according to their findings, IV contrast should be "judicious, rather than routine.

2.2.7.3 Incomplete Colonoscopy Patients

Using oral iodinated contrast for fecal/fluid tagging is a viable option for patients undergoing completion CTC after an incomplete optical colonoscopy on the same day (Chang et al., 2011; Neri et al., 2009).

There are several reasons for failure or incomplete endoscopy including Operator factors: These include things like the endoscopist's experience level and the frequency of cecal intubations.

Patient-related factors: These include having a low body mass index and not preparing the bowels enough. Technical-related factors: These involve conditions such as diverticular disease, previous pelvic surgery, and prior pelvic radiotherapy.

Anatomic factors: These comprise aspects like a tortuous or excessively long colon, looping of the colon (especially in the sigmoid colon), acute flexure angle, and fixation of colon loops (Franco et al., 2017).

The reported percentage of incomplete OC studies varies from 0.4 to 15%. For cases of incomplete OC, it's advisable to schedule a CTC either on the same day or the following day. If opting for a same-day CTC, it's essential to tag any residual stool and fluid.

Patients generally consume 250 mL of 2% barium and 50 mL of non-ionic iohexol (Omnipaque) once they have fully recovered from the incomplete OC. These tagging agents usually take 3–4 hours to reach the colon. Prior to starting CO2 insufflation, a low-dose CT scan is performed to exclude the risk of colonic perforation resulting from the OC (Spada et al., 2020).

The contrast can be given 1.5–3 hours before the planned CTC once the patient has recovered from sedation. Though the delay might not always be sufficient for tagging the

entire colon in every patient, around 72–74% of patients have contrast reaching the distal colon.

Even if the rectosigmoid colon is not reached, the unvisualized portions of the colon during endoscopy are usually adequately tagged. For better tagging of the distal colon, delaying CTC to the next day or another day is recommended, leading to improved fecal/fluid tagging, though it involves the inconvenience of a repeat bowel preparation (Chang et al., 2011; Theis et al., 2016).

The modified protocol for incomplete colonoscopy screening has recently been discontinued, even though it was more convenient for patients by eliminating the need for repeat cathartic bowel preparation. This decision was made due to the clear advantages of using contrast coating for the detection of flat polyps.

It's important to recognize that tagging alone may not offer adequate polyp coating compared to the standard regimen, which involves dry cathartic preparation and dual tagging agents. Consequently, we now prefer rescheduling for a future date with a standard preparation to enhance our ability to detect flat sessile serrated polyps, which are often subtle lesions (Kim et al., 2016).

2.2.7.4 Reduced Cathartic or Non-Cathartic Regimens

While bowel preparation is widely acknowledged as the most burdensome aspect of a CTC screening examination, reducing or removing this component while continuing to use oral contrast to tag remaining fecal and fluid materials could significantly improve patient comfort and adherence.

However, most studies on non-cathartic or reduced cathartic CTC methods have demonstrated that diminishing the quality of bowel preparation adversely affects CTC performance (Fletcher et al., 2013; Zalis et al., 2012).

However, reduced cathartic or non-cathartic CTC could still be considered a viable option, especially in cases where patients are unwilling or unable to prepare their bowels completely with laxatives.

In specific cases involving elderly or frail populations where the main objective of CTC is the detection of malignancy rather than precancerous polyps, non-cathartic CTC may remain a suitable and tolerable screening method, with consistent high performance in malignancy detection (Keeling et al., 2010).

A study conducted in 2012 with 605 participants who did not receive cathartic medications showed that adenomas 10 mm or larger may be accurately detected. However, detection accuracy was lower for lesions smaller than 10 mm in size (Zalis et al., 2012).

There are pointed out drawbacks of non-cathartic screening protocols: The Patient preparation is still necessary stool and remaining fluid must be marked with tagging agents; this could lead to a decrease in accuracy, which could lead to missed lesions and a greater need for colonoscopies, and it is not possible to perform same-day optical colonoscopy without cathartic preparation, and electronic cleansing can introduce its artifacts that add complexity to the interpretation of the study.

Adopting a cathartic-free regime would likely lead to higher screening compliance rates. Additionally, it would mitigate the risks associated with purgative preparations, particularly in patients with known cardiac and renal insufficiency (Pickhardt, 2007).

2.2.7.5 Antispasmodic Medication

During colon imaging, hyoscine butylbromide, often known as Buscopan, is mostly used as an antispasmodic in the UK and Europe. However, a number of nations, like the USA, do not grant licenses for it. Previously, the USA used Glucagon as an alternative.

Studies have found that Buscopan is safer and more cost-effective than Glucagon. However, its efficacy in CTC examinations has not been definitively established (Taylor et al., 2003).

Due to the lack of food and drug administration (FDA) approval in the USA, the use of Buscopan prolongs the duration of the procedure and makes it more challenging to perform. If spasm hinders the adequate distention of the colon during insufflation, additional views such as right lateral decubitus (RLD) and left lateral decubitus (LLD) projections may be necessary to distend the sigmoid (Bortz, 2014).

Buscopan reduces peristalsis and eases spasms by resting the smooth muscles in the gastrointestinal wall. Nevertheless, it frequently causes minor side effects like impaired vision and dry mouth. which typically resolves within 20 minutes.

Nonetheless, these effects can restrict post-examination activities due to visual disturbances. Therefore, patients should be advised to exercise caution with activities like driving until their vision returns to normal. More serious side effects include urinary retention, glaucoma, angina attack, and cardiac ischemia (Bortz et al., 2023).

For dosing and administration, a premedication dose of 20 mg of hyoscine butyl bromide is recommended to be administered intravenously. This dosage has been widely utilized in colonoscopy trials without notable adverse effects. It's noted that higher doses have not yielded additional benefits (Bortz et al., 2023).

Antispasmodic medication should be taken regularly during colonoscopies, according to recent UK recommendations, especially when bowel cancer screening is being conducted.

This recommendation stems from the belief that antispasmodics enhance adenoma detection rates. Antispasmodic agents like Buscopan may decrease motion artifacts and enhance image quality. However, staff administering these agents must undergo sufficient training, whether for IV or intramuscular (IM) administration. They should also be aware of contraindications, including untreated narrow-angle glaucoma, myasthenia gravis, tachycardia, prostatic enlargement with urinary retention, or paralytic ileus (Bortz et al., 2023).

2.2.7.6 CTC Reporting

The CT Colonography Reporting and Data System (C-RADS) was established in 2005 by ACR Colon Cancer Committee, and has been widely adopted since. The main objectives of reporting and data system classifications are to create standardized terminology and report structures, facilitating consistent and reliable communication of findings. This standardization aids in making treatment and follow-up recommendations and enables uniform data classification for research, quality assessment, and patient outcome evaluations.

The original C-RADS system includes criteria for evaluating colorectal lesions (C0–C4) and extracolonic findings (E0–E4), describing polyps and masses by their attenuation, morphology, size, and location, with specific recommendations for both screening and diagnostic CTC.

Polyps in the colon at CTC: A polyp is a uniform soft tissue lesion arising from the colonic mucosa, connected to the bowel wall, and protruding into the colonic lumen, usually measuring 6 mm or more. Larger masses, including tumors of at least 30 mm, are not classified as polyps and are reported separately.

Colonic Mass at CTC: Colonic masses are defined as soft tissue lesions of at least 3 cm. CTC's sensitivity and specificity for detecting colonic masses are nearly 100%, and it is also accurate for colon cancer staging with intravenous contrast. Patients with detected masses at CTC may be referred to colonoscopy or surgery/oncology due to CTC's high detection accuracy, particularly for masses with constricting features.

Feature	Description
Attenuation	• Soft tissue attenuation • Fat—lipoma, fibrolipoma, or inverted • diverticulum (classified as C1)
Morphology	• Sessile—broad-based • Pedunculated—polyp with separate stalk • Flat or laterally spreading tumors • Mass (≥30 mm)
Size	• Large (≥10 mm) • Small (6–9 mm) • Diminutive (≤5 mm)—not typically reported
Location	• Six standardized colonic segments: rectum, sigmoid colon, descending colon, transverse colon, ascending colon, and cecum

Figure 2.2: Explanations of the classification of colon CTCs according to the ACR (Yee et al., 2024).

Colonic Lesions Classification: The CTC report should not only describe the size, location, and morphology of colonic lesions but also provide an overall assessment of the large intestine.

Additionally, the report should evaluate the quality of the examination, considering the adequacy of cleansing, distention, and tagging. In certain cases, the report may also indicate the reader's confidence level (low, moderate, high), especially when there is uncertainty about a finding or when categorizing a lesion as C2a or C2b (Yee et al., 2024).

C-RADS Colonic		
Findings Score	**Definition**	**Management**
C0	Inadequate study and/or awaiting prior comparisons: Inadequate preparation: cannot exclude lesions ≥10 mm owing to presence of fluid and/or feces Inadequate insufflation: one or more colonic segments collapsed on both (views except in suspected myochosis coli—see C2b)	Awaiting prior comparisons. Amend when prior studies are available. Repeat CTC or consider an alternative screening test if inadequate.
C1	Normal colon or benign lesion: No visible abnormalities of the colon No polyp ≥6 mm Lipoma or inverted diverticulum Nonneoplastic findings—eg, colonic diverticula, asymptomatic pneumatosis cystoides coli	Continue routine screening*
C2a	Intermediate polyp or indeterminate finding: Intermediate polyp 6–9 mm, fewer than three in number	Repeat CTC in 3 y or colonoscopy referral recommended†
C2b	Likely benign diverticular finding: Mass-like area such as severe diverticular myochosis coli, muscular hypertrophy, or stricture	Likely benign: recommend repeat CTC in 5 y Uncertain benign: recommend repeat CTC in ≤3 y
C3	Polyp, possibly advanced adenoma: Polyp(s) or subepithelial lesion ≥10 mm Three or more polyps, each 6–9 mm Polyps previously categorized as C2a that have enlarged in size at follow-up	Colonoscopy referral recommended‡
C4	Likely malignant colonic mass: Polypoid mass ≥30 mm or a malignant-appearing mass Lesion compromises bowel lumen or demonstrates extracolonic invasion	Colonoscopy, surgical and/or oncologic consultation recommended‡

Note. —Adapted, with permission, from reference 1. C-RADS = CT Colonography Reporting and Data System, CTC = CT colonography.
*Every 5–10 years.
†For polyps 6 mm and greater, recommend polypectomy in suitable patients versus follow-up study in 3 years, subject to individual patient
circumstance.
‡Communicate to referring physician as per accepted guidelines for communication, such as American College of Radiology Practice Parameter for Communication of Diagnostic Imaging Findings (85). Subject to local practice, endoscopic biopsy may be indicated.

Figure 2.3: Assessment Categories for Colonic Findings in C-RADS Version 2023 (Yee et al., 2024).

2.2.7.7 CTC Interpreting

In order to improve polyp recognition in CTC images, interactive usage of two-dimensional and three-dimensional data sets is necessary. Stacked transverse CT scans are used in two-dimensional imaging, and interactive scrolling is used to trace the colon over its entire length. Essential functions include zooming, panning, adjusting window width and level, and switching between sagittal and coronal planes while correlating specific locations between these planes.

The recommended window level and width settings (-200–0 HU and 1500–2000 HU, in that order) offer a striking contrast between the gas-filled lumen and the soft tissue polyp, and soft-tissue window settings (400 HU in width, 10–40 HU in level) as well as between the fluid pools and polyp or any adhering contrast material. These parameters also match well with readings from optical colonoscopy and aid in distinguishing between fat and soft tissue attenuation.

A variety of formats are used in three-dimensional imaging, such as unfolded cubes, anatomic dissection views, perspective filets, and endoluminal perspectives with active flythrough. The endoluminal viewpoint flythrough with a 120° field of view is the typical format. Expanding the viewing angle past 120° has the potential to improve mucosal coverage and decrease interpretation time, but it may also cause image distortion., reducing polyp visibility and detection accuracy.

Evaluation includes interactive navigation through the colon in both retrograde and antegrade directions. While other three-dimensional formats are usable, there is less documented experience with them. These alternatives can reduce interpretation time by providing a broader view of the colonic mucosal surface, albeit with increased distortion (Ricci et al., 2020; Yee et al., 2024).

2.2.7.8 Electronic Cleansing (EC)

Residual stool and fluid in the colon can negatively impact the evaluation of CTC images, as fecal residue can mimic or obscure colonic lesions, and residual fluid can conceal submerged lesions.

Fecal tagging enhances the CT attenuation of residual stool and fluid by using positive contrast media, such as iodine or barium, administered orally during bowel preparation. This tagging typically occurs the day before the examination or up to three hours prior.

Tagged residue, with high CT attenuation values, can be easily distinguished from soft tissue lesions on two-dimensional images, improving the sensitivity and specificity of CTC. However, tagged residue can obscure the colonic mucosa in endoluminal three-dimensional views, necessitating frequent switches to two-dimensional evaluations to assess submerged areas, which is time-consuming.
EC software addresses this limitation by digitally subtracting tagged residue from CTC images based on their high attenuation values.

The EC algorithm recognizes voxels with CT density values exceeding a preset threshold as tagged residue, making the colonic wall visible in both two-dimensional and three-dimensional images.

This allows for seamless three-dimensional evaluation of the colonic mucosa that would otherwise be obscured, enhancing the overall assessment of the colon.

Digital subtraction of tagged fecal residue from CTC images helps to minimize false-positive and false-negative diagnoses, thereby improving polyp detection. By electronically eliminating residual stool that might be confused with polyps, the accuracy of the evaluation is enhanced.

Moreover, when utilizing endoluminal three-dimensional images, polyps that are hidden by fluid or labeled solid material are easier to spot than in two-dimensional planar views. This process ensures a clearer and more accurate assessment of the colonic mucosa, ultimately improving diagnostic accuracy (Mang et al., 2020).

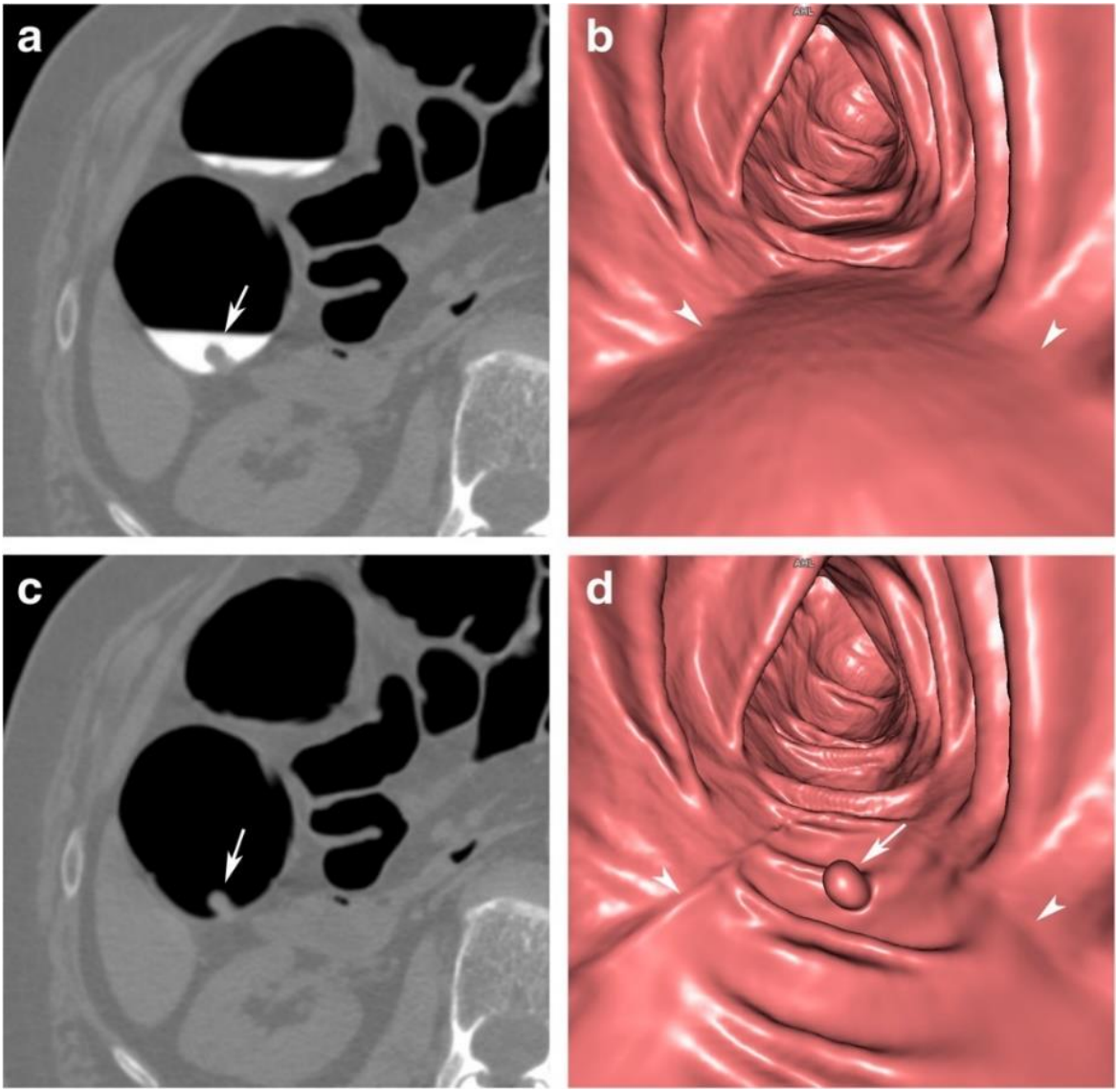


Figure 2.4: Sessile polyp completely immersed in tagged residual fluid in the ascending colon (Mang et al., 2020).

a. Axial 2D View: This view displays a sessile polyp (marked by an arrow) with uniform soft tissue attenuation amidst the tagged hyper-dense fluid.
b. Endoluminal View: In this corresponding view, only a horizontal fluid layer is visible (marked by arrowheads).
c. Electronic Cleansing (EC): Applying electronic cleansing removes the tagged fluid from the 2D view, enhancing the visibility of the colon wall.
d. Endoluminal 3D Views: The polyp is now visible in the endoluminal 3D views, appearing round with a smooth surface (marked by an arrow). A linear artifact is often seen at the air-fluid interface (marked by arrowheads), aiding in identifying parts of the colon wall that were initially submerged.
The haustral folds remain intact during this process.

2.2.7.9 Indication and Contraindication CTC

The majority of patients who are referred for CTC are either unable to have an OC or had an incomplete colonoscopy due to certain conditions. The rate of incomplete colonoscopy ranges from 4% to 25% and tends to increase with age, reaching rates of 22–33% in older individuals.

Reasons for incomplete colonoscopy can include various factors such as: difficulty in reaching the cecum, inadequate bowel preparation, colonic anatomy issues like redundancy or tortuosity (often in the sigmoid colon), severe diverticular disease, acute angles or fixed loops in the colon, adhesions, colonic spasm, being female or older, having a low body mass index, colonic obstruction caused by tumors or strictures (malignant or benign) (Brahmania et al., 2012).

According to ACR guidelines patients with active bowel conditions such as diverticulitis, diarrhea, acute colitis suspected colonic perforation, recent colorectal surgery, or small bowel blockage should not undergo CTC. Additionally, patients with symptomatic abdominal wall hernias involving the colon should avoid CTC. Patients who have had recent endoscopic procedures like biopsy or polypectomy/mucosectomy should hold off on getting CTC for at least a week.

CTC is also not recommended during pregnancy or for those at risk of pregnancy, regular monitoring for anal canal disease, inflammatory bowel disease, and inherited polyposis or nonpolyposis cancer syndromes.

And the clinical indications for CTC include screening Surveillance for patients at moderate or average risk of colorectal cancer, monitoring individuals with a history of colonic neoplasms, and diagnostic assessment for symptomatic patients experiencing gastrointestinal issues such as abdominal pain, anemia, or weight loss, follow-up after incomplete colonoscopy, or for characterizing lesions indeterminate on colonoscopy.

CTC is also used for those who are more likely to experience colonoscopy-related problems (e.g., older age, usage of anticoagulant), those with a colonic stoma, or before colorectal cancer surgery to assess tumor localization and identify synchronous lesions (American College of Radiology (ACR), 2019).

2.2.7.10 CT Radiation Dose

Modern multidetector array CT scanners have advanced capabilities that enable high-quality imaging for CTC These scanners utilize thin overlapping axial sections (1-1.25 mm) across the whole colon in one breath. Imaging is typically performed helically at end-expiratory breath-hold to minimize pressure on the transverse colon from intra-abdominal and diaphragmatic factors.

Adhering to As Low As Reasonably Achievable (ALARA) principle, is crucial to minimize radiation exposure during screening. While the radiation risk associated with CTC is generally low and outweighed by its benefits, efforts are made to use only the necessary amount of radiation, typically lower than that of a barium enema with double contrast (below 5 mSv). Lowering radiation doses can also help reduce incidental findings outside the colon.

Various methods are employed to minimize radiation dose during CTC. These include reducing tube current milliampere (mA) either as a fixed parameter or using automatic dose modulation.

Additionally, adjusting (kVp) can significantly impact radiation dose, particularly in smaller patients, although this may increase image noise in larger patients. Modern CT scanners utilize iterative reconstruction methods that, when combined with dose reduction techniques, achieve substantial dose reduction without compromising image quality.

Practical strategies to minimize radiation dose also involve limiting the scan volume to the colon, excluding unnecessary areas like the liver dome and lung bases. Optimizing colonic distension is essential to avoid the need for repeat scans. Furthermore, focusing repeat scans on specific areas of interest and ensuring proper patient positioning enable effective dose modulation.

While reducing radiation dose may result in increased image noise in extracolonic structures, adjusting slice thickness and window settings can mitigate these effects to enhance interpretation clarity (Chang & Kim, 2018).

Screening CTC is using a low-dose multidetector CT technique, it is usually accomplished without the need for intravenous contrast, with an average radiation Dose Length Production (DLP) of no more than three mSv.

This radiation dose is equivalent to or lower than typical annual background radiation exposure levels. However, in cases involving obese individuals, adjustments to the radiation dose may be necessary to achieve adequate image quality for accurate diagnosis. Obese patients often require higher radiation doses to penetrate deeper tissue layers and obtain clear imaging results. This adjustment ensures that the CTC procedure remains effective and reliable for detecting potential abnormalities in the colon (Ricci et al., 2020).

While efforts are made to keep radiation exposure minimal, adjustments based on patient characteristics, such as body size, may be necessary to optimize diagnostic quality and reliability in CTC screenings. The goal remains to balance effective imaging with the ALARA principle, to minimize unnecessary radiation exposure while maintaining diagnostic accuracy.

2.2.7.11 CT Colonography Training

To ensure optimal performance and patient outcomes, all team members should undergo proper training tailored to their roles. A radiologist with substantial experience in CTC must provide effective leadership.

Maintaining quality assurance across all service aspects, including patient experience, distension, and reporting accuracy, is considered best practice for enhancing performance and outcomes for patients (BSGAR et al., 2021).

With proper training, radiographers can develop the expertise to interpret acquired images accurately during examinations. Having a skilled reader assess the images during scanning allows for adjustments in technique to optimize distension and adapt the patient pathway as needed.

This approach enhances efficiency and ensures patients receive optimal care and outcomes (Haycock et al., 2010; Jensch et al., 2007; Rimes et al., 2019; BSGAR et al, 2021; Thomsen et al., 2016).

Radiographers should receive comprehensive training covering all aspects of CTC, including patient communication, obtaining consent, optimizing distension, navigating the lumen, and troubleshooting. It is important to prioritize the initial clinical evaluation of obtained images.

This enables radiographers to critically evaluate images while the patient is still on the scanner and make decisions about additional imaging, such as administering intravenous contrast or performing a decubitus scan if the initial scans are insufficient (The National CT Colonography Training and Accreditation Programme (NCTCTAP), 2024).

Analyzing high-resolution two-dimension and three-dimension CT images, with optimum gas distended for an appropriate diagnosis, interpreting these CTC images requires additional skills and training since they differ from conventional abdominopelvic CT interpretation and take a longer period. Specific training in CTC interpretation is crucial for independent reporting accuracy.

Without adequate training, there's a risk of perceptual errors in detecting colorectal polyps and cancers, leading to poorer outcomes. As of right now, there is no agreement on the best training approach for CTC interpretation.

The literature consistently highlights the clear benefit of training, especially when personalized and accompanied by reader feedback. To optimize CTC reader training, a more sophisticated and ideally standardized program is needed. This ensures that all learners can attain the high accuracy demonstrated by the technique in research trials (Obaro et al., 2022).

2.2.7.12 CT Colonography at Extracolonic Findings

CT images not only give crucial information about the colon but also reveal details about extracolonic structures (lungs to pelvis), despite low radiation and often no IV contrast.
C-RADS was developed in 2005 by the Working Group for Virtual Colonoscopy and has since become standard for reporting colorectal and extracolonic findings. C-RADS categorizes extracolonic findings: E0 (limited exam), E1 (normal/anatomic variant), E2 (clinically unimportant), E3 (likely unimportant, incompletely characterized), and E4 (potentially important) to (potentially important finding) (Ward et al., 2022).

It was found by Larson et al. that patients with a history of extracolonic cancer have more relevant extracolonic findings (Larson & Pickhardt, 2019).

Early detection of recurrences can improve long-term survival. In a retrospective study of 855 CTC patients, 8.3% had significant E4 findings, including 1.5% with unknown cancers (Ward et al., 2022).

A meta-analysis of 44 studies (49,676 patients) from 1994 to 2017 on CTC screening and CTC for symptom evaluation estimated the frequency of extracolonic discoveries and recommendations for further workup. Less than 3% of asymptomatic cohorts had potentially significant extracolonic abnormalities at CTC, according to the C-RADS categorization. Overall, additional workup was suggested or recommended for about 8% of all extracolonic findings, but this rate dropped to 4% for potentially important findings (Pickhardt et al., 2018).

The United States Preventive Services Task Force (USPSTF) highlighted concerns about incidental extracolonic findings, which occur in 40%-70% of screenings and require follow-up in 5%-37% of cases, with about 3% needing definitive treatment.

These findings can lead to benefits and harms, including unnecessary tests and treatments. Early detection of significant extracolonic findings at CTC can reduce future morbidity, mortality, and costs, especially in patients with E4 lesions.

Additionally, nearly 90% of patients receive reassurance from negative findings, which provides peace of mind. Extracolonic evaluation at CTC also allows for opportunistic screening for conditions like osteoporosis and abdominal aortic aneurysm (AAA) by measuring bone mineral density during routine CT scans (Pooler et al., 2017).

2.2.7.13 Previous Studies on CTC

CTC is an imaging procedure for the colon that uses CT technology and advanced software to create a three-dimensional view. Its purpose is to detect colonic abnormalities such as precancerous polyps and cancer, which may require further evaluation via optical colonoscopy.

Although there is considerable uncertainty over its sensitivity in identifying advanced adenomas and CRC, clinical research indicates that over 90% of polyps bigger than ten millimeters and 78% of polyps larger than 6 mm can be detected.

In the USA, the acceptance of CTC as a recommended CRC screening tool varies, and its use is primarily limited to patients unsuitable for colonoscopy due to other health conditions (Simon, 2016).

When screening patients with major medical issues who are more likely to experience complications from anesthesia, procedure bleeding, or perforation, CTC is a particularly good option. It has been successfully applied to finish colonic screening following an unfinished OC.

Both CTC and OC have equivalent sensitivity for detecting colorectal cancer, with 96% for CTC and 95% for OC (Ricci et al., 2020).

CTC is highly sensitive for detecting large polyps (≥10 mm) and colorectal cancers, and it has good sensitivity for detecting polyps that are 6 to 9 mm in size (Obaro et al., 2022).

Soft tissue lesions measuring three centimeters or more are referred to be colonic masses. CTC's sensitivity and specificity for detecting these masses are nearly 100% (Yee et al., 2024).

ESGAR and the European Association of Radiology (EAR) conducted a meta-analysis of 24 studies involving 4,181 patients. They found that CTC has a sensitivity of 93% and a specificity of 97% for detecting polyps ≥ 10 mm. For polyps ≥ 6 mm, both sensitivity and specificity were 86% (Wessling et al., 2001).

Macari et al. revealed a 93% sensitivity for polyps ≥ 10 mm, 70% for polyps 6-9 mm, and 52% for polyps ≤ 5 mm. Studies showed that multi detector MD-CTC sensitivity decreases for polyps smaller than 10 mm, especially those ≤ 5 mm. However, the likelihood of cancer or progression to cancer is low for polyps smaller than 10 mm (Macari et al., 2002).

MD-CTC demonstrated an overall sensitivity of 83% and specificity of 95%, with a positive predictive value (PPV) of 95% and a negative predictive value (NPV) of 83% for identifying colorectal masses and polyps. For polyps ≥ 10 mm, sensitivity was 92% and specificity was 95% (PPV 92%, NPV 95%). For polyps 6-9 mm, sensitivity was 75% and specificity was 100% (PPV 100%, NPV 90%). For polyps ≤ 5 mm, sensitivity was 88% and specificity was 100% (PPV 100%, NPV 95%) (Devir et al., 2016).

A meta-analysis included 14 full-text articles with a total of 3,578 patients. For detecting polyps ≥ 6 mm, CTC showed a pooled sensitivity of 0.87, a specificity of 0.90, a positive likelihood ratio of 9.08, a negative likelihood ratio of 0.14, and an area under the curve of 0.94. For polyps ≥ 10 mm, the sensitivity was 0.91, the specificity was 0.98, the positive likelihood ratio was 40.36, the negative likelihood ratio was 0.09, and the area under the curve was 0.98.

CTC demonstrates high diagnostic accuracy for detecting polyps ≥ 6 mm and ≥ 10 mm in high-risk colorectal cancer patients, with better sensitivity and specificity for polyps ≥ 10 mm (Bai et al., 2020).

In a study of 109 patients with CRC where colonoscopy was incomplete, there were 59 lesions in total: 20 lesions ≥10 mm, 30 lesions between 6-9 mm, and 9 lesions ≤5 mm. CTC demonstrated per-patient sensitivity of 93% and specificity of 98% in detecting synchronous lesions ≥ 6 mm. For synchronous adenomatous lesions, sensitivity was 89% with specificity of 100%, while for synchronous CRC, sensitivity was 94% with specificity of 100%.

These findings led the study to conclude that CTC is highly accurate for detecting synchronous colonic lesions in patients with obstructive CRC (Flor et al., 2020).

Chapter Three: Methodology

3.1 Introduction

This chapter will cover a number of subjects, including the design of research, study setting, sample size, and study population, study instrument and data collection, ethics committee, and considerations, evaluation of images, data collection, statistical analysis, and the subheadings for these topics.

3.2 Design of Research

This research is a cross-sectional, quantitative retrospective study that does not include any interventional elements, aimed at evaluating CTC sensitivity in comparison to visual colonoscopy while using a pooled preparation for CTC patients. The study was conducted at An-Najah National Hospital, Martyr Khalil Suleiman Hospital, Iben Sina Specialized Hospital, and Al-Razi Hospital. Data were collected from reports spanning the period from January 2019 to June 2024.

3.3 Study Setting

The study was conducted across several hospitals in northern Palestine (West-Bank), including Martyr Khalil Suleiman Hospital (Jenin Governmental), An-Najah National University Hospital, Al-Razi Hospital, and Ibn Sina Specialized Hospital.

Patient archives from these hospitals were accessed to obtain a sample of patients diagnosed with colon cancer or polyps who had colonoscopies and CT colonography performed.

The researchers selected patients from these hospital archives who met the criteria of being diagnosed with colon cancer or polyps and who had received both CTC and CS.

This sample was used to compare the findings and effectiveness of these two diagnostic methods in detecting colon neoplasia.

3.4 Sample Size and Study Population

Inclusion criteria for the study encompassed personal or familial history of colorectal polyps and cancer, symptoms such as bleeding, change in bowel habits, abdominal pain, and iron deficiency anemia. Exclusion criteria comprised a history of familial adenomatous polyposis or hereditary non-polypoid cancer, prior colorectal surgery, suspicion of inflammatory bowel disease, acute diverticulitis, rejection of CTC, high creatinine test, and pregnancy.

A total of 68 patients were enrolled in the study during the period from January 2019 to June 2024, consisting of 27 females and 41 males, ranging in age from 19 years to 77 years, with a mean age of 55.3 ± 13.5 years. All patients underwent the same suboptimal CTC preparation and the same CT scan protocols in all hospitals, and image processing was conducted to analyze and interpret the results.

3.5 Study Instrument and Data Collection

The institutional review board of our university approved this retrospective research. The approvals are shown in Appendices A and B below. The study's objectives were communicated to all participating hospitals, and each hospital provided prior informed consent to proceed with the study.

Additionally, consent was obtained from each institution to access the medical records of the study sample were used for collecting, organizing, and analyzing data. In this study, a retrospective case study design was employed, consisting of the following steps

- Accessing the archiving system of each hospital to retrieve the medical records of the research sample.
- Identifying patients within the sample who underwent CTC, and met the criteria for colorectal neoplasia (tumors or polyps).
- Referring to the same patients' medical records to retrieve results from colonoscopy examinations conducted within a period not exceeding three months from the date of the CTC.
- Establishing significant correlations between each patient's colonoscopy results and CTC detecting.

- Classifying the CTC findings according to the dimensions, form, and placement of Rectocolonic lesions and categorizing colonoscopy examinations as complete or incomplete.
- Entering the collected information into statistical analysis software (e.g., SPSS) to analyze the data and determine the accuracy and sensitivity of CTC in detecting Rectocolonic lesions compared to colonoscopy.

These steps outline the methodology used to retrospectively compare CTC and OC findings, The goal was to evaluate the effectiveness and reliability of CTC as a diagnostic tool for detecting colorectal neoplasia. The analysis sought to offer insights into how well CTC performs and its usefulness in clinical practice for identifying and characterizing lesions in the colon and rectum.

3.6 Ethics Committee and Considerations

Permission was obtained by the researcher from the Palestinian Ministry of Health and the administrations of An-Najah National University Hospital, Ibn Sina Specialized Hospital, and Al-Razi Hospital to view patient records (CT and OC reports).

The approvals are shown in Appendices A and B below. An information sheet was provided to patients, outlining the study's objectives and emphasizing that participation was optional. Participants were assured that their information would remain confidential and would be used solely for scientific research purposes, with no requirement for them to provide identifying information.

Following this, consent was finalized with all hospital departments mentioned above, and their signatures were obtained. Approval from the Scientific Research Ethics Committee at the Arab American University, Institutional Review Board (IRB) was secured with the code number (R-2024/A/133/M), along with approval from the facility for graduate studies at Arab American University Palestine (AAUP).

These steps ensured that the study was conducted ethically and in compliance with established research guidelines, prioritizing patient confidentiality and informed consent.

The role of the researcher was strictly limited to reviewing medical files without interfering with imaging protocols or patient interventions such as radiation exposure, surgical procedures, or direct patient contact.

This approach ensured that the study maintained a non-invasive and observational nature, focusing solely on retrospective data analysis to assess diagnostic accuracy and outcomes related to colorectal neoplasia detection.

3.7 CTC Procedure and Protocol

The CTC procedure described involved the following steps and protocols:

3.7.1 Patient Preparation

Orally iodinated contrast (Omnipaque 300 mg I/ml) was received by patients in a dosage of 20-40 ml based on patient weight, diluted with 1.2 to 1.5 liters of water, with intervals of 3 hours on the same day before the examination.

This contrast was used to mark residual liquid in the bowels and air during bowel cleansing. Patients were required to fast for 8 hours before the examination and to undergo a Glomerular Filtration Rate (GFR) or creatinine test the day before to assess kidney function. Intravenous contrast material was administered as needed by the doctor to evaluate extracolonic organs.

Preparation for Examination: Patient preparation was limited to the use of barium sulfate, bowel laxatives, colon cleansing, and adherence to a specific diet.

3.7.2 CTC Procedure

CTC was conducted using a CT scanner (128-detector). models from Philips and General Electric (GE). A scanogram was obtained to assess the patient's position and scan area while in the supine position.

Scans were performed with the patient in supine, in a cranio-caudal direction, and limited to scan position prone, and right/left decubitus positions.

MD-CTC examination settings included 120 kV, 0.5-second gantry rotation time, and X-ray parameters ranging from 100-250 mA. The collimation was set at 0.5 × 64, with a 5-mm slice thickness, Field of View (FOV) of 320mm, beam pitch of 0.83, table speed of 25 per rotation, and slice increment of 2.5 mm.

Images were obtained during 5-9 seconds of breath-holding under expiration in the supine position, with the scan range extending from the mid-thorax to the inferior edge of the pubis. CT images with a thickness of 2mm to 5mm were reconstructed in coronal and sagittal planes.

3.8 Evaluation of Images

CT images were transmitted to a separate workstation over the network. Initially, 5mm slice thick axial images were reviewed, followed by evaluation of coronal and sagittal multiplanar reformatted images. A volume rendering technique (VRT) computer program, three-dimension, and dissection colon, wasn't used to create virtual colonoscopies for all patients.

Colorectal polyps, cancer, morphological characteristics, colonic location, and were evaluated by dividing the colon into six segments: the rectum, transverse colon, sigmoid colon, descending colon, ascending colon, and cecum. Pathological findings were re-evaluated by modifying window width and level settings.

Fecal matter and residual liquids were marked with iodine contrast, allowing for the differentiation of fecal materials from polyps and masses based on their varied internal structures and iodine contrast content. The CT images were assessed by several radiologists about six doctors, each with more than 6 years of experience in abdominal imaging.

3.9 Optical Colonoscopy Technique

A colonoscopy was conducted within a period ranging from 1 week to 3 months following the CTC, or after incomplete OC. The type of instrument used to detect colonic lesions by endoscopy was the "Olympus Colonoscopy 190" In all hospitals.

The gastroenterologists conducting the colonoscopies were not informed of the CTC findings and had at least five years of experience in performing colonoscopies.

Six sections of the colon were assessed, following a similar approach used in CTC. It's crucial to remember, nevertheless, that not all colonoscopies—from the rectum to the cecum—achieve full vision of the colon due to mass obstructions.

3.10 Data Collection

The study procedure for data collection was depicted in a figure below:

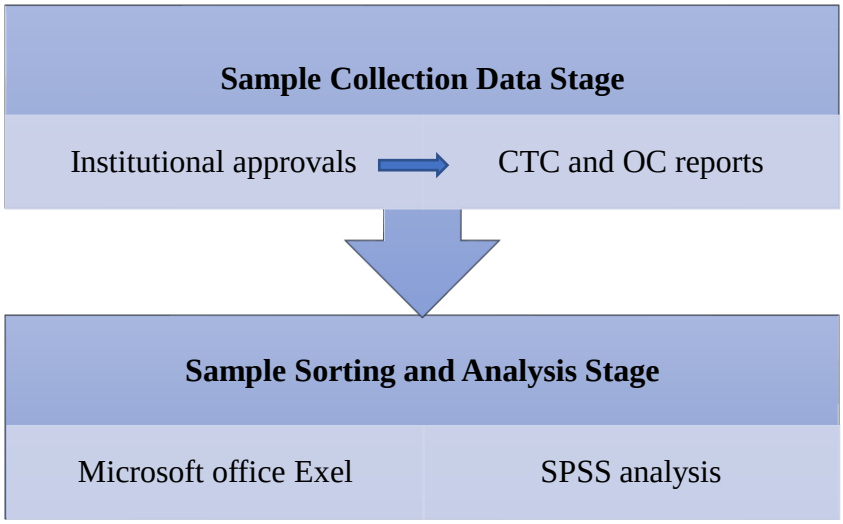


Figure 3.1: Summarize the sample collection procedure

3.11 Lesion Classifications

Lesions detected in anatomical sections that were the same in shape and size by both CTC and OC were classified as true positives. If neither CTC nor OC detected any lesions in the same segment, this outcome was classified as true negatives.

If a lesion identified by CTC was not found in the same segment during conventional colonoscopy, this was categorized as a false positive. Conversely, if a lesion identified during conventional colonoscopy was not detected by CTC in the same region, the conventional colonoscopy was repeated. If no lesions were detected upon repeat, this was considered a false negative result.

3.12 Statistical Analysis

Patients with pathological findings were classified into four groups based on lesion size according to the ACR reporting system: ≥ 10 mm categorized as large, 6 mm - 9 mm as small, ≤ 5 mm as diminutive, and ≥ 30 mm as a mass.

The agreement and sensitivity for detecting colorectal neoplasia findings between CTC and OC was evaluated using statistical methods. The Kappa coefficient and the chi-square statistic (χ^2) were utilized for this analysis. Statistical Package for the Social Sciences (SPSS) version 26 (IBM SPSS Statistics 26) was employed for statistical computations.

The interpretation guidelines for the Kappa coefficient were as follows:

- K = 0 - 0.19 indicated no agreement,
- K = 0.2 - 0.39 indicated weak agreement,
- K = 0.4 - 0.59 indicated moderate agreement,
- K = 0.6 - 0.79 indicated a good level of agreement,
- K = 0.8 - 1 indicated an excellent level of agreement.

The chi-square statistic (χ^2) is employed to evaluate whether there is a significant relationship between categorical variables. It plays a key role in hypothesis testing by determining if the observed categorical data significantly deviates from the expected values, assuming no association between the variables.

Its objective is to determine whether the frequencies observed and the frequencies predicted by a null hypothesis differ noticeably, where no association between the variables exists.

Chapter Four: Results

4.1 Data Collections

The total sample size was 68 patients The samples were collected from four hospitals as follows: An-Najah National University Hospital, Martyr Khalil Suleiman Hospital-Jenin, Al Razi Hospital–Jenin, and Ibn Sina Specialized Hospital – Jenin, (41, 21, 3, 3 receptively) as shown in Table 4.1:

Table 4.1: Distribution of sample collection to hospitals.

Hospital Name	Frequency	Percent
An Najah National Hospital	41	60.3
Martyr Khalil Suleiman Hospital (Jenin)	21	30.9
Al Razi Hospital	3	4.4
Ibn Sina Specialized Hospital	3	4.4
Total	68	100.0

4.2 The Patients Sample

In this study, 68 patients with colorectal neoplasia (tumors and polyps) were included, as shown in Table 4.2. Among them, 41 were identified as males (60.3%) and 27 as females (39.7%). Of these patients, masses were present in 40, while 28 were found to have polyps.

Notably, two patients with masses had two masses located in different regions, varying in size and morphology. Additionally, four other patients had both masses and polyps, and one of these patients had two masses and multiple polyps, all differing in location, type, and size. In total, 42 cancerous masses were detected via colonoscopy, which served as the gold standard for lesion detection in this study.

Among the 28 patients with polyps, 9 had multiple polyps, showing variations in size, location, and morphology. Some patients had two polyps, while others had more. Overall, 49 polyps were detected via colonoscopy.

The patients' ages ranged from 19 to 77 years, with an average age of 55.3 years. The standard deviation was ±13.5 years, with a median age of 58 years and a mode of 59 years. The following table summarizes the patients included in the study, along with the different diagnostic techniques employed.

Table 4.2: Summarizes the contents of the entire research sample regarding computed tomography and colonoscopy for each patient.

Variable	**Branches**	**Number**	
Age	From	19	
	To	77	
Gender	Male	41	Total
	Female	27	68
Colonoscopy Neoplasia	Mass / Multiple Mass	38 / 2	
	Polyp / Multiple Polyps	23 / 8	
	Mass / Polyps	42 / 49	
Competed Tomography Neoplasia	Mass	Mass	Normal
		33	9
	Polyps	null	
Computed Tomography External Finding	Finding	65	
	Not finding	3	
Colonoscopy Procedure Condition	Complete	47	
	Incomplete	21	

4.3 Data Analysis

4.3.1 CT External Finding

Table 4.3: Distribution of sample results in extracolonic examination.

Variable	Frequency	Percent	Cumulative Percent
Finding	65	95.6	95.6
Not Finding	3	4.4	100.0
Total	68	100.0	

By analyzing the CT sample reports, it was found that the following external pathology CT findings: Normal findings were observed in 3 patients (4.4%), while external lumen of colon findings was observed in 65 patients (95.6%).

These findings included liver lesions, kidney stones and cysts, liver size and shape abnormalities, spine degenerative disease, aneurysmal abdominal aorta, heterogeneous appearance of the prostate, metastatic hepatic lesions, lymph node enlargement, free fluid in the abdomen and pelvis cavity, metastasis to the stomach wall, multiple hyperdense and hypodense areas in the liver, pancreatic cancer, enlarged para-aortic lymph nodes, gallbladder stones, soft tissue masses, pleural effusion, splenomegaly, regional lymph nodes, colitis, spleen hypodense mass, colonic diverticula, inflamed appendix, abdominal inflammation, uterus hypodense lesion, and more.

4.3.2 The Polyps

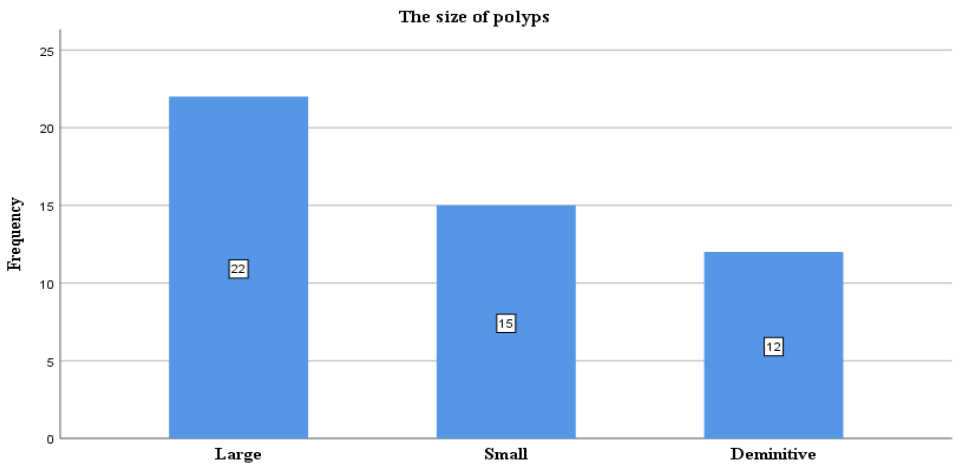
According to the statistical distribution of the 49 polyps, it was found among 28 patients, The polyps are divided according to the ACR classification as follows:

4.3.2.1 Size

Table 4.4: Distribution of polyps according to size.

Size	Frequency	Percent	Cumulative Percent
Large	22	44.9	44.9
Small	15	30.6	75.5
Diminutive	12	24.5	100.0
Total	49	100.0	

As shown Table: the large polyps account for 22 (44.9%), small polyps for 15 (30.6%), and diminutive polyps for 12 (24.5%).



Figer 4.1: Histogram showing the statistical distribution of polyps according to size.

4.3.2.2 Location

Table 4.5: The distribution of polyps based on location.

Location at Colon	Frequency	Percentage (%)
Rectum	9	18.4
Sigmoid Colon	12	24.5
Descending Colon	12	24.5
Transverse Colon	8	16.3
Ascending Colon	2	4.1
Cecum	6	12.2
Total	49	100.0

As shown in Table 4.6: Polyps are located in the rectum in 9 cases (18.4%), sigmoid colon in 12 cases (24.5%), descending colon in 12 cases (24.5%), transverse colon in 8 cases (16.3%), ascending colon in 2 cases (4.1%), and cecum in 6 cases (%12.2).

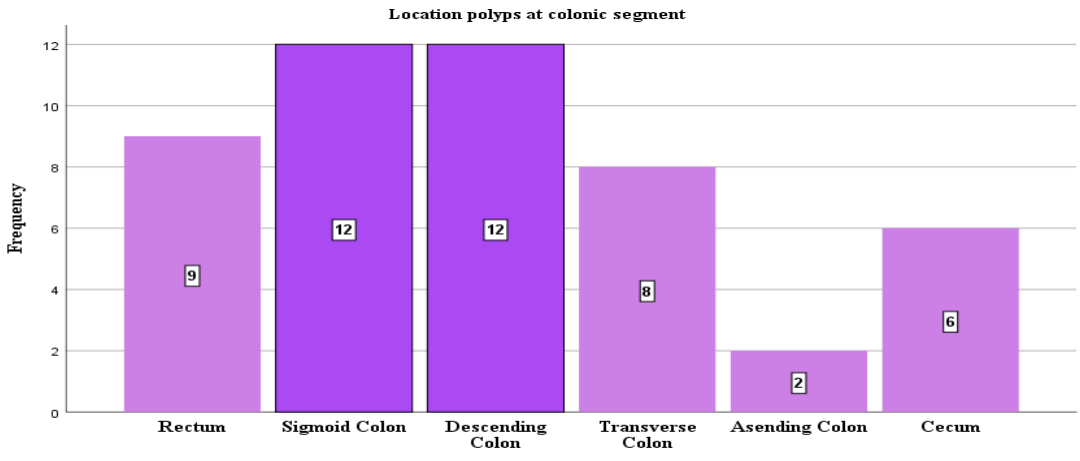


Figure 4.2: Histogram showing the statistical distribution of polyps according to their location in the colon segment.

4.3.2.3 Morphology

Sessile polyps comprise 37 cases (75.5%), pedunculated polyps comprise 9 cases (18.4%), and flat polyps comprise 3 cases (6.1%) as shown in Table 4.6:

Table 4.6: Polyp distribution based on morphology.

Polyp Morphology	Frequency	Percentage (%)
Sessile	37	75.5
Pedunculated	9	18.4
Flat	3	6.1
Total	49	100.0

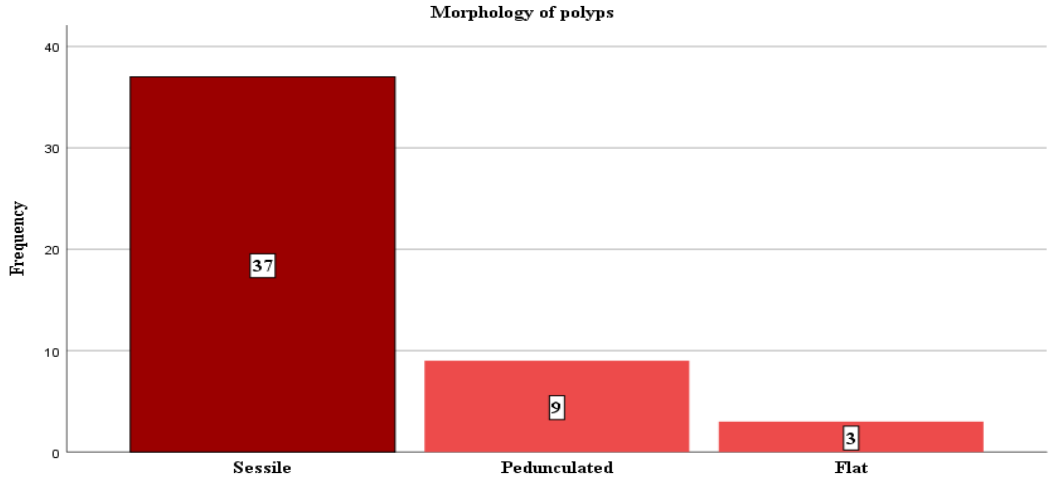


Figure 4.3: Histogram showing the statistical distribution of polyps according to their morphology in the colon segment.

4.3.3 The Masses

According to the Chi-square statistical distribution of the research sample of 40 patients using a CT device as shown in Table 4.7:

Table 4.7: Analysis of the number of cancerous masses detected in the CT scanner inside the colon.

Variable	Frequency	Percentage (%)
Normal	9	21.4
Mass	33	78.6
Total	42	100

A total of 42 masses were identified in 40 patients. Out of these, 33 masses (78.6%) were found, while 9 masses (21.4%) were missed. Regarding the location of the masses at CT and CS as shown in Table 4.8:

Table 4.8: Analysis of the number and location of cancerous masses detected in the CT scanner inside the colon.

Variable / Location	Colonoscopy Frequency	Colonoscopy Percentage (%)	Computed Tomography Detect Masses	Computed Tomography Percentage (%)	Missed Computed Tomography Masses
Rectum	19	45.2	14	42.4	5
Sigmoid Colon	12	28.6	11	33.3	1
Descending Colon	2	4.8	2	6.1	0
Transverse Colon	6	14.3	3	9.1	3
Ascending Colon	2	4.8	2	6.1	0
Cecum	1	2.4	1	3	0
Total	42	100.0	33	100.0	9

In CS results

Total 42 masses: 9 cases (45.2%) were located in the rectum,12 cases (28.6%) were found in the sigmoid colon, 2 cases (4.8%) were detected in the descending colon, 6 cases (14.3%) were situated in the transverse colon, 2 cases (4.8%) were observed in the ascending colon, 1 case (2.4%) was located in the cecum.

In CT results

Total 33 masses: 14 cases (42.4%) were located in the rectum,11 cases (33.3%) were found in the sigmoid colon, 2 cases (6.1%) were detected in the descending colon, 3 cases (9.1%) were situated in the transverse colon, 2 cases (6.1%) were observed in the ascending colon, 1 case (3%) was located in the cecum.

A total of 9 missed masses were detected: 5 cases in the rectum, 1 in the sigmoid colon, and 3 in the transverse colon.

4.3.4 Details All Lesions

The statistical distribution of the CT device compared to the colonoscopy device for all colon neoplasia (masses and polyps) across 68 patients is as follows: A total of 91 colon lesions were identified, with the CT scan detecting 33 masses (48.5%) out of 42. Additionally, 9 masses were missed, along with 49 polyps, resulting in a total of 58 lesions detected by the CT scan (63.7%).

Table 4.9: Details of the sample contents for lesions detected inside the colon by both CT scan and Colonoscopy.

Variable	Branches	Number
Competed Tomography Results	Mass	33
	Normal	9
Colonoscopy Results	Mass	42
	Polyps	49
Location	Sigmoid	12
	Descending	2
	Transvers	6
	Ascending	2
	Rectum	19
	Cecum	1
Polyp Size	Mass	42
	Large	22
	Small	15
	Diminutive	12
Morphology	Sessile	37
	Peduncle	9
	Falt	3
	Mass	42

Table 4.10: The distribution of cancerous masses and polyps detected and undetected by colonoscopy within the colon.

Variable	Frequency	Percentage (%)
Missing Mass	9	21.4
Detected Mass	33	78.6
Detected Polyps	null	null
Missing Polyps	49	100
Missing Masses and Polyps	58	63.7
Total of All Lesions	91	

- No polyps were detected by the CT scan device in any of the patients across all hospitals.

- Cohen's κ was calculated to determine if there was agreement between CT colonography and colorectal colonoscopy in detecting colorectal neoplasia in a sample of 91 individuals. The results showed weak agreement between the two procedures, $\kappa = 0.235$, and $p < .001$.

- Chi-Square = 60.405.

- The sensitivity of CT scan for detecting masses is equal as the below equation:

Sensitivity = Tru positive / (True positive + False Positive)

= TP / (TP + FP)

= 33 / 33 + 9 = 78.6.

- Error Percentage for masses = Missed Detect / Total sample = 9/42 = 21.4.

- Error Percentage for all colorectal neoplasia = 63.7%.

- The sensitivity of CT scan for detecting all colorectal neoplasia = 36.3%.

4.3.5 Colonoscopy Completion Status

Table 4.11: The distribution of colonoscopy completion status.

	Frequency	Percent	Cumulative Percent
Complete	47	69.1	69.1
Incomplete	21	30.9	100.0
Total	68	100.0	

It was found in the study that 47 out of 68 patients (69.1%) successfully completed the colonoscopy examination from the anus to the end of the cecum. However, 21 patients (30.9%) did not complete the entire endoscopy for various reasons. These included the presence of a mass causing colon obstruction, inadequate preparation, and non-compliance due to pain, among other factors.

Chapter Five: Discussion

5.1 Introduction

This section discusses the causes identified in the study and compares them with findings from earlier local and international studies. Additionally, this chapter encompasses the study's conclusions, recommendations, strengths, weaknesses, and suggestions for future research.

5.2 Discussion

CRC remains a significant global health challenge, ranking among the top causes of cancer-related mortality (Siegel et al., 2023). In Palestine, specifically the West Bank, CRC is the second most common cancer, with an incidence rate of 15.3 cases per 100,000 population as reported in 2022. The overall cancer death rate in Palestine in 2022 was high, with CRC contributing to 14.3% of cancer deaths, closely following lung cancer at 16.4% (PHIC et al., 2023).

Early detection and removal of premalignant lesions, such as colorectal polyps, are crucial for reducing CRC mortality. Both CS and CTC are useful techniques for screening CRC and thoroughly inspecting the entire colon.

While colonoscopy is considered the gold standard for identifying colorectal polyps and CRC, it is invasive and can result in complications such as bleeding and perforation. Despite its accuracy, colonoscopy misses 5% of cancers and 10-20% of polyps (De Palma et al., 2018; Mainenti et al., 2004).

CTC developed in 1994, has emerged as a minimally invasive alternative to traditional colonoscopy. It offers several advantages: no need for sedation, lower risk of perforation, and avoidance of infection risks associated with colonoscope use. However, CTC cannot facilitate tissue sampling, necessitating follow-up colonoscopies if abnormalities are detected (Devir et al., 2016; Ricci et al., 2020).

The use of CTC has grown, particularly for patients with incomplete colonoscopies or those with medical conditions that increase the risks of traditional procedures.

For optimal diagnostic accuracy, CTC requires proper bowel preparation, fecal tagging, and adequate colonic distention. These factors are essential to prevent misinterpretation of images and to ensure comprehensive visualization of the colon.

Overall, CTC holds significant promise in CRC screening, offering a noninvasive option with high-resolution imaging capabilities. As imaging and processing techniques continue to advance, the role of CTC in early CRC detection and prevention is likely to expand, contributing to improved patient outcomes and survival rates (Sakamoto et al., 2014).

For CTC to continue to provide high diagnostic accuracy in the detection of colorectal cancer, a number of requirements must be met. These include suitable pretreatment, ideal acquisition circumstances, fecal tagging, and adequate intestinal lumen dilatation. Collapsed colonic segments can be mistaken for annular tumors or may make it more difficult to detect lesions, so adequate dilatation of the colon is crucial.

Previous reports and recommendations suggest that techniques such as automated CO_2 insufflation and dual positioning can improve colonic dilation. There is some controversy regarding the use of spasmolytics before CTC; however, some studies have reported benefits in terms of bowel distention and patient comfort (Sakamoto et al., 2014).

To maximize polyp discovery, CTC image interpretation necessitates the interactive utilization of both two-dimension and three-dimension data sets. In two-dimension imaging, stacked transverse CT images are scrolled through interactively to trace the colon along its length. Essential functions include zooming, planning, adjusting window width and level, and switching between sagittal and coronal planes while correlating specific locations across these planes.

Three-dimensional imaging uses various formats, such as unfolded cube, anatomic dissection views, perspective filet, and endoluminal perspective with active flythrough. These formats enhance the detection and evaluation of polyps by providing different visual perspectives of the colon (Ricci et al., 2020; Yee et al., 2024) .

A study within the English Bowel Cancer Screening Program emphasized the importance of endoluminal three-dimensional evaluations, demonstrating their effectiveness in improving polyp detection rates. Despite being more time-consuming than two-

dimensional interpretation alone, incorporating three-dimensional evaluations into CTC strategies is recommended. A thoroughly cleansed and well-distended colon is essential for a high-quality examination, ensuring optimal results from both two-dimension and three-dimension imaging techniques (Mang et al., 2020)

The first step in achieving a clean colon for CTC involves dietary modifications. Patients are instructed to follow a low-fiber diet, which reduces solid fecal material that could obscure polyps on CT scans. While a high-fiber diet, rich in fruits, vegetables, and grains, promotes regular bowel movements, it also adds residue and bulk that are harder to eliminate during cleansing. A low-fiber diet, on the other hand, facilitates more effective colonic cleansing and enhances stool tagging with oral contrast (Holte et al., 2004; Ricci et al., 2020)

According to ESGAR guidelines, using a cathartic agent and implementing fecal tagging with dietary restrictions are essential preparatory steps before undergoing CTC. Guidelines suggest following a low-residual diet for 24 hours or more before the examination (Beebe et al., 2007).

Patients' reluctance to undergo bowel cleansing is a major barrier to attaining effective CRC screening, whether using OC or CTC (Beebe et al., 2007; Harewood et al., 2002). For high-quality CTC exams, colon cleaning is essential because leftover fluids or stool can produce false-positive and false-negative findings, making diagnosis difficult. Residual fecal marking methods help differentiate fecal material from actual lesions, thereby improving the accuracy of CTC (Barish & Rocha, 2005).

Bowel catharsis for CTC can be achieved using various orally ingested laxatives. Magnesium citrate and sodium phosphate are "dry-preparation" saline cathartic agents that produce less residual colonic fluid, making them ideal for CTC since fluid removal during the procedure is difficult. PEG is a "wet-preparation" agent that results in more residual fluid and is considered a second-choice option for CTC. However, PEG does not cause electrolyte disturbances, unlike dry agents (Ricci et al., 2020).

Oral tagging agents are used to increase the attenuation of residual endoluminal fluid and stool particles, enhancing the visibility of submerged colonic polyps. Without tagging, polyps cannot be distinguished from adjacent untagged fluid due to insufficient

attenuation differences. By using iodinated and/or barium contrast agents to opacify residual fluid, soft tissue polyps become more discernible (Callstrom et al., 2001; Fletcher et al., 2000; Iannaccone et al., 2004).

Tagging agents also reduce reliance on dual patient positioning and the need for high-volume cathartic agents, as they improve polyp visualization regardless of fluid positioning.

They increase the internal attenuation of stool particles, making it easier to differentiate between polyps and stool. Barium contrast agents and iodinated contrast agents are the two primary categories of tagging agents.

Typically, iodine-only or combined iodine and barium regimens are initiated on the day preceding the CTC test. Iodinated agents are particularly effective for tagging residual fluid, while barium is more effective for stool tagging. A combination of both ensures adequate tagging of both fluid and stool (Kim et al., 2014, 2016).

Tagging agents are particularly useful for detecting flat polyps by tagging the mucin coat of these lesions, aiding in their detection. Fecal tagging enhances the sensitivity of CTC and reduces the need for a completely dry bowel, which is usually required for endoscopy procedures (Lefere et al., 2002).

In conducting high-quality CTC, achieving adequate distension of the colon is essential. If a segment of the colon is not sufficiently distended during scanning, it becomes impossible to evaluate for polyps or masses. Optimizing colonic distension during CTC helps prevent the need for unnecessary OC to evaluate collapsed but otherwise normal colonic segments (Burling et al., 2006; Chang & Kim, 2018).

Two common methods used to insufflate the colon during CTC studies are room air and carbon dioxide. CO_2 offers advantages over room air due to its rapid absorption from the colon through normal breathing, with absorption rates approximately 150 times faster than room air, which may contain oxygen and nitrogen. Consequently, patients experience fewer cramps during and after CTC when CO_2 is used (Bortz, 2014; RANZCR, 2013; Singh et al., 2012).

Antispasmodics function by lowering peristalsis and spasms by relaxing the smooth muscle in the colon wall. Antispasmodics are often used during colonoscopies in the United Kingdom, particularly within bowel cancer screening programs, has been recommended. This recommendation is based on the belief that antispasmodics improve adenoma detection rates (Committee, 2012; Rajasekhar et al., 2015)

Antispasmodic agents such as Buscopan can decrease motion artifacts and enhance image quality during colonoscopy. However, staff administering these agents must undergo sufficient training, whether for IV or IM administration. This ensures the safe and effective use of the medication (Horvat et al., 2019; Ingelheim B. & Professional leaflet, 2022).

There is a general agreement on using both supine and prone CTC images to distinguish moving residual stool from fixed polyps and cancer pathologies, as well as to optimally evaluate collapsed segments, and the distension of the sigmoid colon is typically better in the supine position (Callstrom et al., 2001; Morrin et al., 2002).

According to studies, turning a patient from a supine to a prone position causes more colonic distension, particularly in the left and rectum. It has been demonstrated that using the supine and prone postures simultaneously improves the accuracy of polyp detection when compared to using the supine position alone (Halligan & Fenlon, 1999; Morrin et al., 2002; Pescatore et al., 2000).

If spasm hinders the adequate distention of the colon during insufflation, additional views such as RLD and LLD projections may be necessary to effectively distend the sigmoid colon (Bortz, 2014). In our study, it was used supine position only.

Accurate interpretation of CTC necessitates specialized training. The acquired data can be displayed in multiple formats, such as multiplanar reconstructions (coronal, sagittal, and axial), three-dimension endoluminal fly-throughs that mimic a colonoscopy view, and bisected tube 'filet' views (virtual dissection).

Images can be reviewed using either a primary two-dimension or primary three-dimension approach. Although there is no consensus on the preferred method, three-dimension review has shown greater sensitivity for polyp detection in screening patients (Heresbach et al., 2011; Pickhardt et al., 2007).

Regarding the previously mentioned patient preparation factors (diet, colon cleansing, fecal tagging with two types, colonic distension, and antispasmodic drugs) and imaging techniques (such as using both supine and prone positions, training staff radiographers and radiologists, interpreting CTC images interactively with both two-dimension and three-dimension views, and advanced technologies like EC and CAD, these have a direct impact on the quality, sensitivity and accuracy of the image in detecting colorectal masses and polyps of all shapes and types.

However, these factors were not utilized in the study. Instead, the research focused solely on using oral iodine for fecal tagging, conducting imaging in the supine position, and interpreting the images in two dimensions only.

The percentage of not completed colonoscopy testes could reach 10 – 15 %, even by highly qualified endoscopists. This may be due to conditions such as stenosis, obstructing tumors, or abnormal colonic length or shape. In these situations, the sections of the colon that were not visible are evaluated using CTC (Maggialetti et al., 2016; Spada et al., 2014).

It was found by the study that 69.1% of colonoscopy examinations were completed, while 30.9% were not. This highlights the need for alternative solutions to ensure a complete diagnosis of colon lesions.

Patients with incomplete colonoscopies were evaluated, revealing that CTC effectively examines the unseen parts of the colon, enhancing abnormality detection. CTC's significant advantage is its ability to identify extracolonic findings. Unlike colonoscopy, which may struggle with anatomical landmarks, CTC precisely locates colorectal tumors.

Accurate preoperative localization of colorectal cancer is crucial for proper surgical planning, especially in laparoscopic procedures. Additionally, CTC provides precise tumor staging (Singh et al., 2015).

It was found in the study a high rate of diagnosis of conditions outside the colon, with 95.6% of cases identifying external lesions. This was done without using disease classification but by finding all surrounding lesions. Accurately diagnosing the site of external lesions is crucial, as it often leads to the preferred use of surgical operations.

When a patient is diagnosed without any diseases outside the colon, it is considered a good prognosis and discovery, as reassuring the patient is essential for their psychological well-being and the progress of treatment.

According to the study, when colorectal lesions bigger than 6 mm were detected, lower-dose multidetector-row CTC significantly reduced dosage while retaining high sensitivity and specificity. Additionally, it demonstrated excellent sensitivity and specificity for lesions larger than 10 mm (Iannaccone et al., 2003; Macari et al., 2002).

The study was found that, CTC and OC are comparable in detecting clinically significant lesions. Given CTC achieves the same preventive and detection goals as colonoscopy but with fewer resources and lower complication rates, the study suggests it as the preferred screening method (Pickhardt et al., 2003).

The sensitivity of CTC and OC in identifying colorectal cancer is comparable, at 96% for CTC and 95% for OC (Z. Ricci et al., 2020), and Colonic masses, which are soft tissue lesions of at least 3 cm, can be detected with nearly 100% sensitivity and specificity using CTC (Yee et al., 2024).

MD-CTC demonstrated an overall sensitivity of 83% and specificity of 95% for detecting colorectal polyps and masses, with a positive predictive value (PPV) of 95% and a negative predictive value (NPV) of 83% (Devir et al., 2016).

The sensitivity for detecting CRC and advanced adenomas can vary, but clinical studies indicate detection rates exceeding 90% for CRC and polyps larger than 10 mm, and around 78% for polyps larger than 6 mm (Simon, 2016).

In the study, the sensitivity of CTC for detecting colorectal masses was found to be 78.6%, with a non-detection rate of 21.4% In comparison with previous international studies, there is a clear difference in sensitivity. These differences are attributed to the lack of thorough patient preparation, as previously mentioned.

Based on these results, the CT device cannot be considered a reliable diagnostic tool and should not be relied upon as a primary choice for diagnosis or included in early detection programs for colorectal cancer.

It’s important to note that the effectiveness of CTC varies significantly based on the size of the lesions. CTC has demonstrated limitations in detecting individual lesions smaller than 5 mm. However, it's worth emphasizing that diminutive polyps (less than 5 mm) have a very low prevalence of malignancy (approximately 0.25%) and a minimal likelihood of developing cancer (Pineau et al., 2003).

CTC exhibits high sensitivity and specificity in detecting colorectal lesions larger than 10 mm. However, its accuracy diminishes as the size of the lesions decreases, particularly in detecting smaller polyps (Devir et al., 2016; Pineau et al., 2003).

Flat lesions pose a challenge for detection with CTC because they are less conspicuous on three-dimensional endoluminal imaging, often leading to false-negative results. Unlike sessile or pedunculated polyps, flat lesions do not significantly alter the shape of the colon, making them more likely to be missed.

It has been shown by several studies that flat lesions detected during conventional colonoscopy were overlooked by CTC, highlighting the diagnostic difficulty faced by CTC with these types of lesions. CTC is known to be highly sensitive for detecting large polyps (≥10 mm) and colorectal cancers, with good sensitivity also noted for polyps sized 6 to 9 mm (Obaro et al., 2022).

In symptomatic patients from high-prevalence societies, sensitivity rates for polyp detection ranged from 29% to 59% for small polyps, 47% to 82% for medium-sized polyps, and 63% to 92% for large polyps(Kim et al., 2007).

The Multicenter Study reports a sensitivity of 90% for detecting adenomas 10 mm or larger and 78% for adenomas sized 6 to 9 mm. However, CTC's detection rate for polyps smaller than 5 mm is notably low based on available studies (Johnson et al., 2008).

According to a meta-analysis involving 4,181 individuals, CTC demonstrated a sensitivity of 93% and a specificity of 97% for identifying polyps larger than 10 mm. For polyps measuring 6 mm or larger, both sensitivity and specificity were 86% (Wessling et al., 2001).

Macari et al. reported a sensitivity of 93% for polyps ≥ 10 mm, 70% for polyps 6-9 mm, and 52% for polyps ≤ 5 mm. Their findings also indicated sensitivity rates of 92% and

75%, respectively, for polyps ≥ 10 mm and 6-9 mm, with higher specificities (95% and 100%) across all size categories (PPV and NPV values provided) (Macari et al., 2002).

The study results showed that, based on the CT reports, no polyps of any type or size were detected. In contrast, colonoscopy identified polyps larger than 1 cm in 44.9% of cases (22 out of 49 polyps). This suggests that the CT device is not suitable for detecting polyps. These findings underscore the importance of preparing patients according to the international protocol used for CTC.

Despite these challenges, detecting flat lesions is crucial because 15-30% of colorectal cancers originate from serrated polyps rather than adenomatous polyps. Therefore, effective preventive strategies must target not only adenomas but all premalignant conditions, including flat lesions (Gluecker et al., 2002; Laghi et al., 2002; Singh et al., 2015; White et al., 2009).

In summary, CTC is considered a valuable diagnostic tool for examining the entire colon and is regarded as a viable alternative to colonoscopy and other existing colorectal cancer screening methods. However, high accuracy in detecting colon cancer is dependent on adherence to international protocols for patient preparation and the use of advanced CTC imaging techniques.

5.3 Conclusion

CTC is considered a valuable diagnostic tool for examining the entire colon and is viewed as a viable alternative to colonoscopy and other colorectal cancer screening methods. However, in this study, a moderate sensitivity of 78.6% was exhibited by CT scans for detecting masses, with a significant error rate of 21.4%, highlighting the need for caution when relying solely on CT scans for mass detection.

Additionally, limited sensitivity was demonstrated by CT scans for detecting polyps, with none of the patients studied showing polyp detection. These findings underscore the limitations of CT scans in comprehensive diagnostic applications and suggest that good patient preparation and additional imaging techniques are needed to improve detection accuracy for both polyps and masses, as well as other abnormalities.

5.4 Recommendations

Based on the findings of this study, it is recommended that CTC should not be solely relied upon for the detection of colorectal masses and polyps due to its moderate sensitivity and significant error rate.

The observed sensitivity of 78.6% for mass detection and the complete lack of efficacy in detecting polyps indicate that, while CTC can be a useful tool, it must be complemented by other diagnostic methods to ensure comprehensive and accurate detection of colorectal abnormalities.

Enhancing CTC diagnostic accuracy necessitates meticulous patient preparation, including fecal tagging (with iodine and barium), colonic cleansing, dietary adjustments, staff training (technicians and radiologists), and advanced technology (e.g., EC, CAD, viewing both two-dimensional and three-dimensional images, and ensuring adequate colonic dilation).

Future research should focus on the development and integration of supplementary diagnostic technologies or methods to improve the detection rates of polyps and other colorectal anomalies, thereby optimizing overall screening efficacy.

Additionally, advancements in CT imaging techniques and post-processing algorithms could further reduce misinterpretation rates and enhance the reliability of CTC as a non-invasive alternative to optical colonoscopy.

In the next study, an intervention by the researcher will be conducted to compare the results between a patient undergoing CTC preparation according to the international protocol and a patient who was not prepared.

5.5 Strength of the Study

Focusing specifically on patients suffering from colon cancer and polyps, two separate indicators were provided by this study: the sensitivity of CT imaging in detecting these lesions within the colon and the effectiveness of the protocol used for their detection.

Access to information was made available by the institutions where the research was conducted, and the cooperation of their employees facilitated the researcher's access to correct information to the greatest extent possible.

The study was conducted retrospectively, without any intervention by the researcher in the sample, whether in relation to the patients or the devices used for detecting colon cancer and lesions, thus reducing bias. The current reality of the protocol utilized in CTC for detecting colon cancer and polyps in Palestinian hospitals was revealed, emphasizing the most significant weaknesses and shortcomings to provide insights relative to global standards.

While the sample size was considered fairly robust, it is important to note that larger sample sizes generally result in more accurate outcomes.
The importance of modern technology and tools in detecting colon cancer and polyps was underscored by this study. However, tools such as CAD, three-dimensional imaging, and EC are completely absent from the CTC protocols in use.

Practical implications: The findings of the study are of practical significance and contribute to the existing body of information in the area.

Ethical considerations: Ethical guidelines were followed in the study, which included obtaining informed consent from participants, ensuring their voluntary involvement, and protecting their privacy and confidentiality. These guidelines also involved minimizing potential harm to participants, maintaining integrity in data collection and reporting, and disclosing any conflicts of interest.

The combination of these factors and their interconnection contributed to the strength of the study and enhanced the possibility of its general application.

5.6 Limitations

Sample Size: The greater the number of cases, the better the results that will be yielded by the study. Conducting a prospective study of patients' cases ensures better attention to the results, as the time gap between the colonoscopy and the CTC examinations is minimized, making the results more comparable.

The geographical area should be expanded to include the largest number of hospitals from various Palestinian cities. Limiting the use of two-dimensional imaging in reports and avoiding the simultaneous utilization of three-dimensional imaging for the same colon cancer site enhances the accuracy of disease detection results.

Limiting the report writing to one radiologist may not be optimal, as practical and scientific experience varies among doctors. To enhance detection results, it is preferable for multiple radiologists to review the same patient's images.

5.7 Future Work

Expanding research on CTC sensitivity in identifying polyps and colon cancer, could involve several avenues of investigation and potential future work:

Comparative Studies: Conduct comparative studies between CTC and other screening modalities such as FIT, or sigmoidoscopy. This would help understand the relative sensitivity, specificity, and overall efficacy of CTC compared to traditional screening methods.

Longitudinal Studies: Track patients over time in longitudinal studies to provide insights into the progression of polyps to cancer and the effectiveness of CTC in detecting these changes early. Regular screenings of individuals at risk for colon cancer could be included.

Improving Imaging Techniques: Investigate advancements in imaging techniques such as the use of artificial intelligence (AI) algorithms for image analysis to improve the sensitivity of CTC, EC, and CAD. AI could assist in more accurate detection and characterization of polyps and early-stage cancers.

Population-based Studies: Conduct population-based studies to assess the real-world effectiveness of CTC as a screening tool for colon cancer. Large-scale screenings of individuals from diverse demographic backgrounds would help understand how well CTC performs in different populations.

Risk Stratification: Explore the potential for risk stratification models to identify individuals who would benefit most from CTC screening. This could involve integrating genetic, lifestyle, and other risk factors to tailor screening recommendations to individual patients.

Patient Experience and Acceptance: Investigate patient experience and acceptance of CTC compared to other screening methods. Understanding patient preferences and barriers to screening can help improve uptake and adherence to screening programs.

Cost-effectiveness Analysis: Perform cost-effectiveness analyses comparing CTC with other screening modalities. This would involve assessing not only the direct costs of

screening but also the downstream costs related to follow-up procedures and treatment of detected abnormalities.

Advanced Polyp Characterization: Explore the use of advanced imaging techniques such as virtual colonoscopy with computer-aided detection for improved characterization of polyps. This could help distinguish between benign and malignant lesions more accurately.

Impact on Patient Outcomes: Investigate the impact of CTC screening on patient outcomes such as mortality, morbidity, and quality of life. Long-term follow-up studies can provide valuable data on the effectiveness of CTC in reducing the burden of colon cancer.

Integration with Clinical Practice: Study the integration of CTC into routine clinical practice, including its role in triaging patients for colonoscopy and its incorporation into screening guidelines.

Conducting a research study to detect colon cancer and polyps by using different types of modern technology CT imaging devices, such as CT Photon Counting, and CT Deuel Energy, and its efficiency in detecting colon cancer and polyps by reducing patient preparation procedures and dose.

These avenues of future research can further enhance our understanding of the sensitivity of CTC for detecting colon cancer and polyps, ultimately leading to improved screening strategies and better outcomes for patients.

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Appendices

Appendix A: MOH Approval

State of Palestine
Ministry of Health
Education in Health and Scientific Research Unit

دولة فلسطين
وزارة الصحة
وحدة التعليم الصحي والبحث العلمي

Ref.: ....
Date:..................

الرقـــم: عحا/٣٠٦/٢٠٢٤
التـاريخ: ٢٠٢٤/١٢/[illegible]

عطوفة الوكيل المساعد لشؤون المستشفيات والطوارئ المحترم،،،

ق.أ. الأخت مدير عام الإدارة العامة لتكنولوجيا المعلومات المحترمة ،،،

تحية واحترام...

<u>الموضــوع: تسهيل مهمة بحث</u>

يرجى تسهيل مهمة الطالب: **محمد فايز محمد الذيب -برنامج علوم التصوير الطبقي والرنين المغناطيسي** – الجامعة العربية الامريكية، بعنوان:

"The CT confidence Reading for Colorectal Polyps Detection"

حيث سيقوم الطالب بجمع معلومات عن حول موضوع البحث من خلال مراجعة ملفات المرضى وذلك في،

-مستشفى الشهيد خليل سليمان الحكومي

مع العلم ان مشرف الدراسة: د. محمد الجمل، د. عبد السلام خلف

على ان يتم الالتزام بالمحافظة على اخلاقيات البحث العلمي وسرية المعلومات، وعدم التعرض للمعلومات التعريفية للمشاركين.

على ان يتم تزويد الوزارة بنسخة PDF من نتائج البحث، التعهد بعدم النشر لحين الحصول على موافقة وزارة الصحة.

مع الاحترام...

د. عبد الله القواسمي
رئيس وحدة التعليم الصحي والبحث العلمي

نسخة: عميد كلية الدراسات العليا المحترم/ الجامعة العربية الامريكية

Telfax.:09-2333901 scientificresearch.dep@gmail.com تلفاكس: 09-2333901

Appendix B: AAUP Approval

Arab American University
Faculty of Graduate Studies

الجامعة العربية الأمريكية
كلية الدراسات العليا

2024/2/17

الى من يهمه الأمر

تسهيل مهمة بحثية

تحية طيبة وبعد،

تُهديكم كلية الدراسات العُليا في الجامعة العربية الأمريكية أطيب التحيات، وبالإشارة الى الموضوع أعلاه، تشهد كلية الدراسات العُليا في الجامعة أن الطالب **محمد فايز محمد الذيب** والذي يحمل الرقم الجامعي 202113182 هو طالب ماجستير في برنامج علوم التصوير الطبقي والرنين المغناطيسي ويعمل على رسالة الماجستير الخاصة به بعنوان:

" The CT Confidence Reading for Colorectal Polyps Detection "، تحت إشراف الدكتور محمد الجمل والدكتور عبد السلام خلف. نأمل من حضرتكم الإيعاز لمن يلزم لمساعدته للحصول على المعلومات اللازمة للدراسة، علماً أن المعلومات ستستخدم لغاية البحث فقط وسيتم التعامل معها بغاية السرية، وقد أعطي هذه الرسالة بناءً على طلبه.

وتفضلوا بقبول فائق الاحترام

عميد كلية الدراسات العليا

د. نوار قطب

كلية الدراسات العليا
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Appendix C: IRB Approval

Arab American University
Institutional Review Board - Ramallah

الجامعة العربية الأمريكية
مجلس اخلاقيات البحث العلمي – رام الله

IRB Approval Letter

Study Title: "A Comparison Between Colonoscopy and Computed Tomography Colonography in Detection of Colorectal Neoplasia".

Submitted by: Muhammad Faiez Muhammad Atheeb

Date received: 4th July 2024

Date reviewed: 17th July 2024

Date approved: 19th August 2024

Your Study titled **"A Comparison Between Colonoscopy and Computed Tomography Colonography in Detection of Colorectal Neoplasia"** with the code number **"R-2024/A/133/M"** was reviewed by the Arab American University Institutional Review Board - Ramallah and it was approved on the 19th of August 2024.

Sajed Ghawadra, PhD
IRB-R Chairman
Arab American University of Palestine

الجامعة العربية الأمريكية - فلسطين
مجلس اخلاقيات البحث العلمي - رام الله
IRB-R
ARAB AMERICAN UNIVERSITY-PALESTINE
INSTITUTIONAL REVIEW BOARD - RAMALLAH

General Conditions:

1. Valid for 6 months from the date of approval.
2. It is important to inform the IRB-R with any modification of the approved study protocol.
3. The Bord appreciates a copy of the research when accomplished.
4. The previous approval No.: "R-2024/A/28/N".

رام الله – فلسطين

Tel: 02-294-1999 **E-Email:** IRB-R@aaup.edu **Website:** www.aaup.edu

مقارنة بين تنظير القولون والتصوير المقطعي المحوسب للقولون في الكشف عن أورام القولون والمستقيم

محمد فايز محمد الذيب

د. عبد السلام أحمد خلف

د. محمد عبدالله الجمل

د. سامر محمد مهنا

د. أسامة علي خدرج

ملخص

مقدمة

يعد سرطان القولون والمستقيم ثالث أكثر أنواع السرطان تشخيصًا وسببًا للوفيات المرتبطة بالسرطان في الولايات المتحدة الأمريكية، ويؤثر بشكل خاص على الرجال تحت سن الخمسين. وفي فلسطين، يعد سرطان القولون والمستقيم ثاني أكثر أنواع السرطان شيوعًا، مع ارتفاع معدل الإصابة به. وتصنف الزوائد اللحمية في القولون والمستقيم، والتي يمكن أن تؤدي إلى سرطان القولون والمستقيم، على أنها ورمية أو غير ورمية، مع احتمال تحول الأورام الغدية إلى أورام خبيثة. ويعد الكشف المبكر من خلال الفحص مثل تنظير القولون أمرًا حيويًا لمنع سرطان القولون والمستقيم. ويوفر تصوير القولون المقطعي المحوسب، وهو بديل أقل تدخلاً من تنظير القولون والمستقيم، دقة مماثلة ولكنه يتطلب التحضير المناسب للفحص الفعال، مع حساسية مماثلة لتنظير القولون والمستقيم للكشف عن تشوهات القولون والمستقيم.

الهدف

تهدف الدراسة إلى تقييم فعالية تصوير القولون المقطعي المحوسب مقارنة بالتنظير الضوئي للقولون في الكشف عن أورام القولون والمستقيم في المستشفيات الفلسطينية وتحسين أساليب التشخيص.

الطريقة

هدفت الدراسة التحليلية المقطعية الاسترجاعية إلى مقارنة حساسية التصوير المقطعي بالانبعاث الضوئي للقولون (OC) للكشف عن الأورام الخبيثة في القولون والمستقيم لدى المرضى. حللت الدراسة 68 مريضًا باستخدام بيانات استرجاعية (2019–2024) من أربعة مستشفيات في مستشفى النجاح الوطني ومستشفى الشهيد خليل سليمان ومستشفى ابن سينا التخصصي ومستشفى الرازي. كان لدى المشاركين سلائل أو سرطان في القولون والمستقيم وخضعوا للتصوير المقطعي بالانبعاث الضوئي تحت تحضير دون المستوى الأمثل. قارن التحليل الإحصائي بين حساسية التصوير المقطعي بالانبعاث الضوئي والتنظير الضوئي.

النتائج

كشف التصوير المقطعي بالانبعاث الضوئي عن 78.6% من الكتل لكنه فشل في الكشف عن أي سلائل، مع وجود اتفاق ضعيف (κ كوهين = 0.235) بين التصوير المقطعي بالانبعاث الضوئي والتنظير الضوئي. كانت حساسية الكشف عن الأورام الخبيثة في القولون والمستقيم 36.3% فقط، مع معدل خطأ مرتفع بلغ 63.7%.

الاستنتاج

أظهرت تقنية التصوير المقطعي المحوسب حساسية معتدلة للكشف عن الكتلة ولكنها لم تكن فعالة في تحديد السلائل. وتسلط هذه النتائج الضوء على الحاجة إلى الالتزام بالبروتوكولات الدولية لتحسين دقة تقنية التصوير المقطعي المحوسب للفحص الشامل للقولون والمستقيم.

الكلمات المفتاحية: تنظير القولون، التصوير الطبقي المحوري للقولون، سرطان القولون.