# Influence of surgeon-related factors on outcome after colon cancer resection

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LUND
UNIVERSITY

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**Abstract:**

Poor postoperative outcomes following colon cancer (CC) resection are influenced by multiple factors, including both patient-related characteristics as well as surgeon-related factors. However, the influence of surgical specialization, surgeon resection volume and surgeon gender on patient's postoperative outcome, after complex procedures such as emergency CC resection, remains incompletely understood.

This thesis investigates the impact of surgeon-related factors on postoperative morbidity, mortality and long-term survival after CC surgery.

The thesis is based on four papers, all built on register data retrieved from the Swedish Colorectal Cancer Registry (SCRCR), primarily focusing on emergency procedures, but Paper III also includes elective procedures. The study cohorts included adult patients who underwent CC resections between January 1, 2010, and December 31, 2020. A standardized review manual was used to validate registry data and extract additional variables from the patients' medical records. In Paper I, Paper II and Paper III a cohort of patients from Helsingborg hospital was used, whereas Paper IV includes a multicenter cohort involving ten hospitals in the southern of Sweden. Outcomes were analyzed using logistic regression for binary variables and Kaplan-Meier and Cox regression methods for survival analyses.

In paper I, short-term postoperative outcomes were compared across surgeons with different specializations and annual resection volumes. Complication rates were similar between colorectal surgeons (CS) and acute care surgeons (ACS) but were higher among patients operated on by general surgeons (GS). Complication rates were most frequent among surgeons with the highest annual resection volumes. Mortality rates did not differ across surgeon specialty or volume categories.

Paper II demonstrated that the long-term survival was comparable in patients operated on by CS and ACS, but significantly shorter in patients undergoing emergency resections by GS.

Paper III showed no surgeon gender-related differences in outcomes among patients undergoing elective CC resections. However, after emergency resections, patients treated by female surgeons had fewer postoperative complications, fewer non-radical ($R_1$) resections, fewer reoperations, and required less care at the Intensive Care Unit (ICU). Although the 30-day mortality was similar for patients operated on by male and female surgeons, long-term survival was significantly shorter among patients operated on by male surgeons.

Paper IV validated the findings in paper III, in a multicenter setting. Results showed fewer complications and reoperations for patients operated on by female surgeons, but no difference in short-term mortality between groups of patients. Long-term survival was shorter among patients operated on by male surgeons.

Across the included studies, surgeon-related factors were found to influence the patients' postoperative outcomes after emergency CC resection. The observed disparities, particularly those associated with surgeon gender, emphasize the importance to further investigate the underlying mechanisms driving these disparities.

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*To Otto,*

*You will never do a whole lot,*
*unless you're brave*
*enough to try*

*-Dolly Parton*

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# Abstract

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# Original Papers

1. Engdahl J, Öberg A, Bergenfeldt H, Edelhamre M, Vedin T, Bech-Larsen S, Öberg S, Effects of surgical specialization and surgeon resection volume on postoperative complications and mortality rate after emergent colon cancer resection, BJS Open 2023.
2. Engdahl J, Öberg A, Bech-Larsen S, Öberg S, Impact of surgical specialization on long-term survival after emergent colon cancer resections, Scandinavian Journal of Surgery 2024.
3. Engdahl J, Öberg S, Bech-Larsen S, Bergenfeldt H, Vedin T, Edelhamre M, Öberg S, Short- and long-term outcome after colon cancer resections performed by male and female surgeons: A single-center retrospective cohort study, Scandinavian Journal of Surgery 2024.
4. Engdahl J, Larsson P-A, Jolbäck P, De La Croix H, Bexe Lindskog E, Öberg S, The influence of surgeon gender on postoperative outcome after emergent colon cancer resections, Manuscript submitted.

# Abbreviations

| | |
|---|---|
| ACS | Acute Care Surgeon |
| AL | Anastomotic Leakage |
| ASA | American Society of Anesthesiologists |
| BMI | Body Mass Index |
| CC | Colon Cancer |
| CCI | Charlson Comorbidity Index |
| CEA | Carcinoembryonic Antigen |
| CME | Complete Mesorectal Excision |
| CRC | Colorectal Cancer |
| CRM | Circumferential Resection Margin |
| CS | Colorectal Surgeon |
| CT | Computed Tomography |
| DFS | Disease Free Survival |
| EHS | European Hernia Society |
| FAP | Familiar Adenomatous Polyposis |
| FIT | Fecal Immunochemical Test |
| FOBT | Fecal Occult Blood Test |
| GS | General Surgeon |
| HNPCC | Hereditary Non-Polyposis Colorectal Cancer |
| ICU | Intensive Care Unit |
| IL-6 | Interleukin-6 |
| MDT | Multidisciplinary Tumor Board |
| MR | Magnetic Resonance |
| MSI | Microsatellite Instability |
| NCS | Non-Colorectal Surgeon |
| OS | Overall Survival |
| CFS | Cancer-Free Survival |
| SCRCR | Swedish Colorectal Cancer Registry |
| SWD | Surgical Wound Dehiscence |
| TME | Total Mesorectal Excision |
| TNM | Tumor Node Metastasis |
| OS | Overall Survival |
| WHO | World Health Organization |

# Forword

Surgery is a craft passed from one surgeon to another through guidance, observation, and hands-on practice.

The practice of surgery evolves through an ongoing cycle of reflection, adaptation, and refinement, a cycle that extends throughout a surgeon's entire professional career. This cycle is facilitated both by continuous self-assessment and by the reflection and interaction between interns, residents and senior colleagues. These exchanges of experience and reflections that may occur in luminous moments or in times of greater severity and difficulty, form us as professionals. This continuous process is central in development of the individual surgeon, since every operation includes both technical and cognitive elements, but the process also involves judgement, teamwork and communication skills, that can be refined in the search of improved outcome for future patients. The overall goal of surgery is removal of the disease and prolong the patients' life with less suffering and improved quality.

The aim of this thesis is to deepen the understanding of surgeon-related factors that may have an impact on clinical practice patterns and ultimately on the patient' outcome. Increased awareness of such differences may provide important insight to variation in surgical outcomes and highlight opportunities for improvement. Importantly, this thesis does not seek to categorize surgeons as an end. Rather, the distinctions made are a necessary means to explore the variation in surgical practice and to develop a deeper understanding of how diverse practices may shape patient care. The ultimate purpose of the thesis is constant; to enhance surgical quality and to ensure the best possible outcome for our patients, by mapping the landscape of surgeon specific factors.

# Thesis at a glance

| Paper | Aim | Method | Result |
|---|---|---|---|
| I<br>Effects of surgical specialization and surgeon resection volume on postoperative complications and mortality rate after emergency colon cancer resection | Investigate the effect of surgical specialization and surgeon resection volume on short-term outcome after emergency colon cancer resection. | Retrospective cohort study of all patients that underwent emergency colon cancer resection between 2010-2020 at Helsingborg hospital. Surgeons were categorized by specialization and by annual resection volume. Short-term outcome were compared across surgeon groups. | Emergency resections were performed in 235 (21%) patients. Morbidity was similar between patients operated on by colorectal- and acute care surgeons, but complication rates were higher for general surgeons. No differences in mortality were observed across surgeon groups. |
| II<br>Impact of surgical specialization on long-term survival after emergent colon cancer resections | Analyse effect of surgeon specialization on patients long-term outcome after emergency colon cancer resection | Retrospective analysis of all patients with emergency colon cancer resection between 2010-2020 at Helsingborg hospital. A comparison of OS and CFS in patients operated on by surgeons with different specializations. | OS and CFS were similar for colorectal surgeons and acute care surgeons, but significant shorter for patients operated on by general surgeons compared with those operated on by colorectal- and acute care surgeons. |
| III<br>Short- and long-term outcome after colon cancer resections performed by male and female surgeons: A single-center retrospective cohort study | Evaluate the effect of surgeon gender on postoperative short- and long-term survival after colon cancer resection | A retrospective review of both elective and emergency colon cancer resections performed at Helsingborg Hospital between 2010-2020. A comparison between morbidity, mortality and long-term surival between patients operated on by male and female surgeons. | Coloncancer resections were performed in 1 113 patients (79% elective, 21% emergent) by 23 male and 9 female surgeons. Outcomes after elective surgery were similar, but after emergency resections patients operated on by female surgeons had fewer complications, reoperations, ICU admissions, $R_1$ resections and better long-term survival. |
| IV<br>The influence of surgeon gender on postoperative outcome after emergency colon cancer resections | Study the effect of surgeon gender on patients short- and long-term outcome after emergency colon cancer surgery – a multicenter cohort study | Retrospective multicenter analysis of all emergency colon cancer resections performed between 2010-2020 at ten Swedish hospitals. A comparison of short- and long-term outcome for patients operated on by male and female surgeons. | Among 1 307 patients operated on with emergency procedures, 84% by male surgeons and 16% by female surgeons. Patients operated by female surgeons had fewer postoperative complications, reoperations, and longer OS and CFS. |

# Introduction

In studies on colorectal cancer (CRC), cancers of the colon and the rectum are often analyzed together as a single disease. This is a reasonable approach, as the colon and rectum are anatomically connecting parts of the same organ system and share many features. As a results, many studies report outcome and treatment strategies for CRC as a unified group. However, important differences exist between colon- and rectal cancer, in terms of treatment strategies and outcomes. These differences are particularly pronounced in the emergency setting, where management and treatment strategies diverge substantially.

This thesis focuses exclusively on colon cancer (CC), with particular emphasis on emergency surgical presentation, and excludes rectal cancer to achieve a more homogeneous study population and to allow for a more accurate interpretation of surgeon-related outcomes. Throughout the thesis, colon-specific data are used when available, when not, CRC data are presented and identified as such, reflecting the structure of existing literature.

## Epidemiology

Worldwide, CRC afflicts over 1.9 million patients annually and accounts for more than 900 000 deaths, making it the second leading cause of cancer-related mortality globally (1). CRC is the second most common diagnosed cancer among women and the third most diagnosed cancer in men (2).

The global distribution of CRC varies in both incidence and mortality. Europe, Australia and New Zeeland have the highest incidence rates of CRC in the world, though mortality rate, due to CRC, is notably high in Eastern Europe.

After introduction of screening programs and advancement in treatment, the incidence rates of CC have declined in many western countries. However, in the past years, the incidence of CRC in younger adults (25-45 years old) has increased, rising from 8.6 per 100 000 in 1992 to 12.9 per 100 000 in 2018 and represents 10-12% of all CRC patients (3, 4). The reasons for this increased incidence are not completely understood, especially since most of these patients do not have identifiable hereditary risk factors. However, lifestyle and dietary factors appear to contribute to CRC development in young patients, following same risk patterns that are observed in older populations (4).

In Sweden, CRC is the third most common form of cancer, following prostate and breast cancer. Approximately 7100 patients are diagnosed each year, including around 5000 patients with CC and 2100 patients with rectal cancer. The Swedish incidence and sex distribution of CRC largely reflect the global trends (3).

## Screening

The European Commission has since 2003 recommended population-based screening for CRC with fecal occult blood testing (FOBT) in women and men aged 50-74 years to enable detection of cancer at a potentially curable stage (3).

In Sweden, organized CRC screening was introduced in 2014 and has been recommended across all Swedish regions since 2022. Implementation is ongoing, with full national coverage expected by autumn 2026. Approximately 913 000 screening invitations are expected to be distributed annually.

Evidence from randomized clinical trials and meta-analyses demonstrate that FOBT screening is associated with a reduction of 16% in relative risk of CRC mortality. In the Swedish screening program, the fecal immunochemical test (FIT) is used, with a biennial interval for individuals aged 60-74 (5).

Hence, endoscopic detection and removal of adenomas significantly reduce CRC incidence and mortality (7). According to the Swedish National Guidelines, the adenoma detection rate should be at least 25% in individuals over 50 years of age, and as the risk of malignant transformation increases with adenoma size (3).

## Epidemiology of emergency presentation

The proportion of patients with CC who present with emergency symptoms widely differs between studies but is approximately 30% (6, 7). This variability is likely attributable to differences in how emergency presentation is defined. According to the international guidelines from the World Society of Emergency Surgery, large bowel obstruction accounts for roughly 80% of the patients with emergent CC presentation, while remaining patients present with perforation or bleeding.

# Etiology

The pathogenesis of CRC is complex and involves an interplay between hereditary and non-hereditary factors. More than 95% are adenocarcinomas arising from the colonic mucosa, typically originating from adenomatous polyps (3). The progression from adenoma to carcinoma occurs through the conventional adenoma or serrated adenoma pathways. Other histological types are rare and include neuroendocrine tumors, lymphomas, melanomas, and squamous cell carcinomas and are managed according to separate guidelines, rather than the standard CRC pathway.

Most CRCs are sporadic while approximately 25% of patients have a family history of CRC and 5-10% of patients have a hereditary syndrome. The most common hereditary syndromes are Lynch and familial adenomatous polyposis (FAP). Lynch syndrome accounts for 2-5% of CRC cases and results from DNA mismatch repair (MMR) gene mutations. FAP is caused by APC gene mutations and is characterized by multiple adenomas with highly malignant potential.

Age is the most important non-modifiable risk factor, with about 70% of patients diagnosed after 65-years of age and CRC is uncommon before the age of 40 (8). The median age at diagnosis of CC in Sweden is approximately 71 years for men and 73 years for women (3).

Lifestyle factors contribute substantially to CRC risk, with diet accounting for 30–40% of cases worldwide (11). Inflammatory bowel disease, high intake of red meat and alcohol, smoking, obesity, and physical inactivity, increase the CRC risk (12–19). Protective factors include physical activity, intake of dairy products and whole grains (21) and long-term use of acetylsalicylic acid use (20), while the evidence for dietary fiber and coffee remains inconsistent (22–24).

## Pathophysiology of emergency presentation

The core difference in pathophysiology between elective and emergency CC patients, is the acute systemic inflammatory response that typically characterizes patients with emergency presentation. In patients with obstruction or perforation, elevated preoperative levels of proinflammatory cytokines are commonly present, particularly interleukin-6 (IL-6) and C-reactive protein (CRP) (8). However, this inflammatory response, is also partly driven by the tumor burden, a feature presented in elective patients as well, though generally to a lesser extent. IL-6 is released by tumor cells as part of tumor-host response and is a key mediator of systemic

inflammation. It stimulates hepatic production of acute-phase proteins and contributing to development of cancer-associated cachexia. This high inflammatory burden results in an impaired immune system, creating systemic stress and a potential immunosuppression that not only increases the risk of postoperative complications but may also have an impact on long-term oncological outcomes (9). A study by Shiga et al., demonstrated that a preoperative elevated levels of IL-6 was associated with higher risk of CRC recurrence (10).

# Clinical presentation

The initial symptoms of CC may be vague and diffuse. Altered bowel habits and the presence of blood in the stool are traditionally viewed as high-risk signs of CRC, but most patients initially present with less specific symptoms (3). A combination of symptoms, including gastrointestinal bleeding, persistent changes in stool frequency or consistency, tenesmus, diarrhea, constipation, abdominal pain or distention, and systematic features including unintended weight loss or thromboembolic events, is associated with an increased risk of CRC.

**Figure 1.** Intra-abdominal view of a dilated colon due to an obstructing colon cancer. Photograph by Jan Nilsson.

The most common presentation of emergency CC is bowel obstruction, occurring in 80% of patients (11). Initially, symptoms are often not specific and may include intermittent abdominal pain and constipation, due to partial luminal obstruction. Undiagnosed, progressive obstruction of the colon can result in abdominal distension and if complete obstruction occurs, the disruption of flatus and stool passage is observed. If the ileocecal valve is incompetent, vomiting may occur, and distension of the small bowel may develop, while distension of the large bowel then tends to be less pronounced.

Colon perforation occurs in 10-20% of patients presenting with obstructing CC and may develop either proximal to the tumor, usually in the cecum due increased wall tension according to Laplace´s law, or at the tumor site (12). Patients will typically present with peritonitis, nausea and vomiting with a risk of progression to sepsis and hemodynamic instability.

Gastrointestinal bleeding resulting in hemodynamic instability is an uncommon presentation of emergency CC. In a Swedish study, analyzing data from the Swedish Colorectal Cancer Registry (SCRCR), only 4% of patients required operative intervention primarily for bleeding (13).

# Standardized care

In Sweden, standardized care was introduced in 2015, to reduce diagnostic delays and improve quality of care for patients with suspected CRC (3). According to Swedish National Guidelines, suspicion of CRC should be raised, when one or more specific criteria are met:

- Visible blood in stool without alternative source identified
- Unexplained iron-deficiency anemia
- Persisting changes in bowel habits for more than 4 weeks in patients over 40 years of age combined with positive FIT
- Suspicious findings on proctoscopy, rectoscopy (rigid sigmoidoscopy), or digital rectal examination
- Radiological/histopathological, or colonoscopy findings indicating CRC

### Fecal hemoglobin

Over the last decade, FIT has become widely used to support diagnosis of CRC and it has become standard since it specifically detects human hemoglobin. In symptomatic patients, a negative FIT is associated with a very low risk of CRC, with a reported negative predictive value of 99.8-99.9% (14).

# Preoperative comorbidity and risk

Preoperative assessment of surgical patients can rely on a variety of scoring systems and are developed to evaluate the different dimensions of the risk prior to surgery. These systems vary in their purpose and focus, some are designated to assess comorbidity burden, others to estimate the physiological or the operative risk. Others assess frailty and functional status. They are not interchangeable, since each instrument captures complementary aspects of the patient’s overall health.

## Charlson Comorbidity Score

CRC predominantly affects the aging population, underscoring the importance of comprehensive comorbidity assessment. Several classification systems have been developed to classify comorbidity conditions, including the Charlson Comorbidity Index (CCI) and Elixhauser Comorbidity Score (15).

In 1987, Charlson et al. introduced the CCI, an index designed to predict a patient´s risk of mortality within the first postoperative year (16). The CCI includes a range of chronic diseases, each assigned a score of 1-6 based on its associated mortality risk. Patients older than 50 years of age get additional points. The CCI can be used both as a preoperative tool for risk stratification but also postoperatively, as comorbidity burden strongly influences the patient´s postoperative outcome.

The CCI was chosen for this thesis because it provides an objective and diagnosis-based measure of comorbidity that generates a score predicts the mortality risk, making it simple to apply and use in surgical research. In contrast, the Elixhauser index includes a broader range of comorbidities, was originally developed for administrative data, and does not provide a single summary score.

## American Society of Anesthesiologists Classification

In 1941, the American Society of Anesthesiologists (ASA) published the first version of a classification system for assessing patients' preoperative physical status, including examples of diagnoses for each ASA-class (17). In the 1960s, the contemporary ASA classification was proposed by Dripps et al. However, it was implemented without the originally suggested diagnostic definitions, contributing to increased interobserver variability among anesthesiologists.

The primary purpose of the current ASA classification is to evaluate a patient´s physiological reserve at the time of surgical assessment. However, this reserve may change prior to surgery or be altered through preoperative optimization. Furthermore, it is important to emphasize that the ASA classification should not be used as the only determinant of operative risk. While the system estimates the burden of systemic disease, it lacks a definition of the severity the of disease, leading to variability in scoring between anesthesiologists. In addition, it does not account for several important perioperative risk factors, including smoking, a history of difficult airway, or refusal of accepting blood products. Therefore, ASA classification is to be considered as one component of a comprehensive preoperative risk assessment. Patients classified as with ASA III-IV with additional risk factors require more extensive preoperative planning and optimization throughout the surgical pathway (17).

# Clinical workup

## Elective patients

The gold standard of diagnostics for CC is colonoscopy, due to its high sensitivity and specificity for detecting malignant tumors (3). In addition, it allows for tissue sampling of suspicious lesions. Colonoscopy is considered a relatively safe procedure, with a perforation rate of less than 1/1 000 often related to polypectomy (5). When colonoscopy is not feasible, usually due to anatomic or technical limitations, computed tomography of the colon (CT colonography) is recommended, with the inherent disadvantage of not being able to secure tissue samples. The Swedish National Guidelines recommend CT scan of the thorax and the abdomen as part of the standard staging workup to detect systemic disease and/or locally advanced cancer. In selected patients, magnetic resonance imaging (MRI) of the abdomen can be used for pre-operative local staging of CC, with at least as good accuracy as CT. A disadvantage of MRI, however, is that it is more resource consuming and not available at all centers.

Baseline laboratory evaluation typically includes Carcinoembryonal Antigen (CEA). CEA was first described and characterized by Gold and Freedman in 1965, and is an oncofetal antigen, produced in the normal fetus, but only found in small amounts in healthy cells among adults (18). CEA circulates in patients with gastrointestinal malignancies and is produced by 90% of CRC, making it useful as a disease marker. However, due to its low sensitivity in early-stage CRC, it is unsuitable for screening. Failure of CEA levels to return to normal after surgical resection may indicate residual disease or inadequate resection.

## Emergency patients

In the emergency setting, time constraints frequently limit the ability to perform colonoscopy prior to surgery. In some cases, even full staging with CT thorax, cannot be completed preoperatively, resulting in pulmonary metastases remaining undetected until after surgery.

Assessment of nutritional status is an important factor of the preoperative workup for patients with CRC. A systematic review published in 2023, identified preoperative serum albumin as a meaningful indicator of nutritional status in both emergent and elective CRC patients, demonstrating that hypoalbuminemia is significantly associated with greater postoperative morbidity, increased surgical complications, and longer hospital stay (19).

Overall, these investigations constitute the foundation of the clinical workup for CC, though their use may be limited in emergency settings.

## Multidisciplinary Tumor Conference

The Multidisciplinary Tumor Conference (MDT) is a structured meeting involving surgeons, radiologists, pathologists, oncologists, and specialist nurses, who review each patient´s clinical, radiological and pathological findings. The objective of the MDT is to develop an individual, evidence-based treatment plan for patients with CC, aligned with the Swedish National Guidelines for Management of CRC (3).

In Sweden, 96% of patients with electively processed CC, were discussed at a pre-treatment MDT conference in 2024, with emergency operated tumors excluded from this assessment (20). The evidence regarding the impact of MDT is limited, however, cohort studies have demonstrated that MDT participation is associated with more comprehensive preoperative staging, a higher number of patients receiving oncological treatment, increased rates of radical resections, and improved survival for patients with locally advanced CC (3).

With its integrated expertise from several medical disciplines, MDT participation has been shown to improve staging accuracy and promote adherence to evidence-based guidelines. Furthermore, MDT meetings contribute to education, facilitate learning, and transparency in complex clinical decision-making.

In Sweden, preoperative and postoperative MDT review is a routine part of the CC care pathway. In contrast to the elective pathway, preoperative MDT discussion for patients presenting with emergency CC, is generally not feasible due to the acute clinical presentation and the need for immediate surgical decision-making. However, according to the 2024 Swedish National Quality Report for CRC, 98% of patients with CC, both emergency and elective patients, were discussed at a postoperative MDT conference (20).

## Staging

The Tumor Node Metastasis (TNM) classification system was first introduced in its primary form in the 1950s (43). The system describes the anatomic extent of disease by categorizing tumors based on assessment of three components: the extent of primary tumor growth through the layers of the colon wall (T) (Figure 2), the presence or absence of visible lymph node engagement (N), and the presence or absence of distant metastasis (M). Numerical subcategories are added to each component to indicate the extent and severity of disease progression.

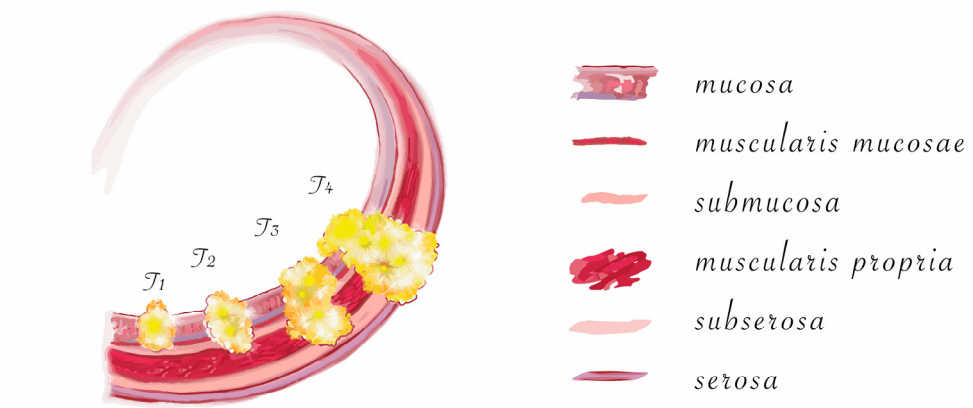


**Figure 2.** Tumor (T) stage according to the TNM classification, showing increasing depth of tumor invasion from T1 to T4. Illustration by Kristine Scherman. Reprinted by permission.

There are two different TNM classifications cTNM, a clinical classification used to evaluate the tumor to enable selection of therapy, and pTNM, a histopathological classification used as a guide for adjuvant therapy and prognosis calculation. The TNM system is subsequently consolidated into stage groupings, which provide a clinically meaningful overview of the extent of the disease. In tumor stage I-II, the cancer is restricted to the large intestine whereas for stage III, local lymph nodes are involved and for tumor stage IV, distant metastases are present (Table 1).
Approximately 40-45% of patients with CRC will develop metastases at some point during the course of the disease. Distant metastases are detected in 20% of patients at the time of diagnosis. Among patients who undergo curatively intended treatment for stage I-III disease, approximately 15-20% will develop metachronous metastases following completion of therapy (3).

**Table 1.** Stages of colorectal cancer according to the TNM-classification and stadium.

| Stage | Tumor Characteristics | Lymph Node Involvement | Distant Metastasis |
|---|---|---|---|
| **I** | Tumor invades submucosa or muscularis propria (T1-2) | None (N0) | None (M0) |
| **II** | Tumor extends beyond muscularis propria (T3-T4) | None (N0) | None (M0) |
| **III** | Any depth of tumor invasion (T1-4) | Regional lymph node metastases (N1-N2) | None (M0) |
| **IV** | Any tumor depth | Any nodal status | Distant metastases present (M1) |

**Note:** T, Tumor. N, Lymph node. M, Metastasis. Valdman et al. 2025 (3).

# Preoperative management

Mechanical bowel preparation was historically regarded important to reduce intraluminal fecal content to prevent anastomotic leakage (21). However, since 1990s, several studies have demonstrated that there is no advantage of mechanical bowel cleansing. A large Swedish randomized clinical trial involving 1 343 patients undergoing colorectal surgery, showed no difference in overall complication rates between patients who received bowel preparation and those who did not (22). In addition, bowel preparation was poorly tolerated and did not improve patient's outcome.

According to the 2025 Enhanced Recovery After Surgery (ERAS) guidelines, routine mechanical bowel preparation is not recommended for colonic surgery (23). However, mechanical bowel preparation may be considered in selected patients undergoing rectal surgery, particularly when a diverting stoma is planned. Importantly, when mechanical bowel preparation is used, the addition of oral antibiotics is recommended, in combination with intravenous antibiotics prophylaxis, as this has been shown to reduce postoperative infectious complications.

The first recorded use of antibiotic prophylaxis in colorectal surgery was described in 1939, and by the 1970s there was clear evidence that antibiotic prophylaxis significantly reduced morbidity and mortality after colorectal surgery (24). Colorectal surgery is at its best a clean-contaminated procedure and strong evidence support that a single dose of antimicrobial prophylaxis, administrated within 60 minutes of the incision, effectively reduces postoperative infections (23). Antibiotic regimens should provide coverage against both aerobic and anaerobic bacteria, although the optimal combination of antibiotic agents has not yet been established (24).

In emergency CRC surgery, mechanical bowel preparation and oral antibiotic prophylaxis are generally not feasible or appropriate but intravenous antibiotic prophylaxis administered prior to incision remains both feasible and essential.

# Treatment of CC

## Surgery

The first documented successful CC resection was performed by Dr Jean Francis Reybard of Lyon in 1823 and consisted of a sigmoid colectomy with an end-to-end anastomosis (25). The patient survived but the procedure was criticized and considered controversial by the Paris Academy for Medicine. However, by 1880, ten resections of the colon had been reported and three were considered successful. Early surgical techniques were performed primarily using blunt dissection.

Today, the primary treatment of CC remains the surgical resection. Standard oncological surgery involves segmental removal of the affected portion of the colon with *en bloc* resection of the associated mesocolon, including a segment of at least 10 cm on both side of the tumor (3). The extent of the colonic resection is determined by the vascular anatomy and the distribution of regional lymph nodes. This approach includes central ligation of the supplying arteries and corresponding draining veins and lymphatic nodes, which ensures adequate lymphadenectomy for oncological clearance. In addition, a thorough exploration of the peritoneal cavity is mandatory to assess the presence of metastatic disease (26).

Since 2016, the Swedish National Guidelines for Colorectal Cancer recommended minimally invasive surgery as the technique of choice for both colon and rectal cancer resections (3). Minimally invasive techniques are associated with improved short-term outcomes, including reduced postoperative pain, fewer abdominal wall complications, and shorter hospital stay compared with open surgery. When adequate oncological resection is performed, open surgery offers no advantages over laparoscopic approaches in terms of long-term oncological outcomes.

According to data from the SCRCR, more than 70 % of elective CC resections were performed laparoscopically in 2024 (20).

### Emergency CC resection

In Sweden, a total of 3 521 patients underwent surgical resection for CC in 2024, 11% were operated on in the emergency setting and 89% underwent elective procedures (20).

According to the Swedish National Guidelines for Colorectal Cancer published in 2025, patients presenting with obstructive CRC can, in selected cases, be

converted from an emergency setting to an elective surgical setting, provided that their clinical condition does not require immediate resection (3). Furthermore, in patients with left-sided obstruction, the guidelines recommend either a proximal diverting stoma or self-expanding metal stents (SEMS) to relieve obstruction, particularly in patients with locally advanced disease.

When resection is performed, standardized oncological principles should be strictly followed, including central vascular ligation, preservation of an intact mesocolic fascia and achievement of an $R_0$ resection (3). If there is uncertainty regarding the feasibility of performing a resection that fulfils these criteria, decompression with a diverting stoma is preferred. Following resection, stoma formation is recommended in patients with poor general condition, significant comorbidity, steroid use or fecal peritonitis.

Open laparotomy remains the predominant approach for emergency CC and is reported as the most frequent used technique in both national and international series. In a study by Vallance et al. 2019, using data from the British National Health Service on patients undergoing emergency CRC resection, 78.9% of procedures were performed using an open approach, while 22.1% procedures were initiated laparoscopically. However, 18.7% of these cases required conversion to open surgery. Interpretation of these findings is limited by selection bias, as laparoscopic surgery was less commonly used in patients with higher ASA classifications and more advanced tumors, making it difficult to attribute improved outcomes solely to the surgical approach (27). Nevertheless, patients who underwent laparoscopic CC surgery experienced a shorter hospital stay and lower 90-day mortality compared with patients undergoing open resection (27).

In the emergency setting, laparoscopic colectomy is a technical challenge due to factors including bowel dilatation, tissue fragility, and/or fecal contamination due to obstruction or perforation. Consequently, conversion rates are high, and laparoscopic approach is reserved for carefully selected emergency patients.

Emergency CC surgery presents several additional challenges compared with elective procedures. Technical complexity is often increased due to distension of the colon and occasionally of the small bowel, which may impair visualization and limit access to the tumor. To facilitate decompression, purse-string sutures may be placed over the cecum or appendix, allowing controlled evacuation of colon content. Effective decompression enables safer bowel handling and improves intraoperative assessment of tumor location. However, decompression may be difficult to achieve and increases the risk of fecal contamination. In cases of bowel perforation, extraluminal fecal spillage may lead to severe sepsis and/or septic shock. Under such circumstances, principles of damage control should be considered, including control of contamination, hemodynamic stabilization, management of bowel injury, and, when indicated, delayed abdominal closure (28). In addition, a thorough exploration of the abdominal cavity is mandatory to assess for peritoneal carcinomatosis, liver metastases, or other signs of advanced disease, which may influence intraoperative decision-making.

For right-sided colon tumors, a right hemicolectomy is usually be performed. If the risk for anastomotic leakage is considered high, or if the patient is deemed unfit to tolerate such a complication, creation of an ileostomy is recommended (3). An extended right hemicolectomy is recommended if the tumor is located in the transverse or proximal left colon.

In the left part of the colon, several surgical options exist (3). Tumors located in the sigmoid colon are typically treated with segment resection, followed by either primary anastomosis or stoma formation. The hypogastric nerve plexus should be identified and preserved whenever possible. Ligation of inferior mesenteric artery may be performed either close to its origin from the abdominal aorta ("high tie") or distal to the origin of the left colic artery ("low tie"), depending on the lymph node involvement. Current evidence does not demonstrate a survival benefit associated with routine high tie ligation. Reconstruction after sigmoid resection is generally achieved with an anastomosis between the descending colon and the proximal rectum. For tumors located in the distal sigmoid, a high anterior resection is recommended.

At present, there are no universally accepted criteria defining the extent of reginal lymph node dissection in patients with CC. All lymph nodes are considered regional, and the lack of sub-classification may lead to uncertainty regarding adequate resection margins during surgery (29). According to Ueno et al., resection of the mesocolon and bowel with margin of 10 cm on either side of the tumor is sufficient, and more extensive bowel resection beyond the regional pericolic tissue does not appear to improve oncological outcomes (29).

## Self-Expanding Metal Stents

The European Society of Gastrointestinal Endoscopy (ESGE) guideline strongly recommends, with a high-quality evidence, Self-Expanding Metal Stents (SEMS) as a bridge to surgery in patients with emergency obstruction in the left side of the colon, rectosigmoid colon, sigmoid colon, descending colon, and splenic flexure, while excluding rectal cancers (30). Furthermore, the ESGE recommend a 2-week interval until resection when colonic stenting is performed as a bridge to elective surgery in patients with curable left-sided CC. The American Society of Colon and Rectal Surgeons clinical practice guidelines argue that SEMS are successfully placed in 77-81% of patients, with a perforation rate of 2% to 9% of patients (31). Several studies argue that converting the emergency to an elective procedure, through a SEMS or temporary stoma, may reduce patients' postoperative morbidity and mortality (3, 32).

# Postoperative recovery

Enhanced Recovery After Surgery (ERAS) is a perioperative care concept introduced in its first formal protocol in 2005, aimed at optimizing patients´ recovery and improving the postoperative outcome (33, 34). A central component of ERAS is prehabilitation, which focuses on strengthening patient´s physical and physiological resilience before surgery, including exercise, nutritional optimization, and smoking and alcohol termination. In colorectal surgery, ERAS protocols have been shown to reduce perioperative physiological stress, facilitate early mobilization, and promotes a faster return to baseline functions.

Early postoperative management focuses on hemodynamic stabilization, pain control, fluid/electrolyte balance and sepsis treatment. Although ERAS principles are more difficult in the emergency setting, several elements can be adopted to support gastrointestinal recovery, including early mobilization, early oral intake, and minimizing perioperative opioid use. Early detection of postoperative complications is critical, as these patients undergoing emergent procedures has a higher risk of anastomotic leakage, sepsis, and cardiopulmonary events. Close clinical surveillance combined with low threshold for laboratory testing and diagnostic imaging is essential to improve outcome (35).

Colorectal surgery is associated with a high risk for postoperative deep venous thrombosis and pulmonary embolism. Evidence supports the routine use of low-molecular-weight heparin as an effective prophylaxis in these patients (36, 37).

In a population-based English study by Vallance et al., including 15 516 patients undergoing emergency CRC resection, laparoscopic surgery was associated with a shorter length of stay compared with open resection (median 8 versus 12 days) and lower 90-day mortality compared with open surgery (27). After emergency resection, patients often experience greater physiological stress due to obstruction, perforation, or/and sepsis, and therefore require more intensive postoperative monitoring than patients undergoing elective surgery.

After curative surgery, CEA levels typically decline and are normalized within 6 weeks. Persistent elevated or rising levels thereafter may indicate residual disease or recurrence and should lead to further investigations (38).

Hospital readmissions are regarded as an indicator of healthcare quality, but evidence suggest readmission alone is a poor proxy for overall quality of care, since it is strongly influenced by patients comorbidities, disease severity and healthcare system factors (39). Variation in readmission thresholds, patients support systems, and different postoperative follow-up routines may vary between hospitals, which further complicates comparisons between studies and underscore the need for caution in interpreting readmission rates.

# Oncological treatment

## Neoadjuvant chemotherapy

Patients with stage I-III CC are typically offered direct surgical resection. However, in patients with more advanced tumors, T4 and/or N2 and pMMR, neoadjuvant chemotherapy can be beneficial in reducing the risk of $R_1$ resection and improve patient's long-term postoperative outcome (3). Guidelines for neoadjuvant treatment of locally advanced tumors include both chemotherapy and antibody treatment.

The FOXTROT trial concluded that six weeks of preoperative neoadjuvant oxaliplatin-fluoropyrimidine neoadjuvant chemotherapy can be safely administered to patients with operable CC, resulting in histopathological downstaging, fewer incomplete resections and better long-term outcome compared with adjuvant chemotherapy for patients with T3-4, N0-2, M0 CC (40). According to the Swedish National Guidelines for CRC, neoadjuvant treatment should be reserved for patients with World Health Organization (WHO) performance status 0-1, pMMR and non-obstructing tumors (3). There are studies indicating that neoadjuvant immunotherapy can be beneficial for patients with locally advanced dMMR tumors. However, no randomized trials have yet been published, therefore, the current recommendation remains to offer these patients surgery upfront (41).

## Adjuvant chemotherapy

Adjuvant chemotherapy after curative CC surgery has been investigated in several trials since the 1980s (42). A meta-analysis of these studies showed a 10-12 % improvement in 5-year survival with adjuvant 5-flourouracil-based (5-FU) treatment in patients with stage III CC.

The optimal timing of adjuvant treatment for patients after CC surgery remains a matter of debate. According to guidelines from European Society for Medical Oncology (ESMO), adjuvant chemotherapy should be initiated as soon as possible, preferably within 8 weeks after surgery (26). Starting adjuvant chemotherapy more than 8 weeks after surgery is associated with a reduced OS compared to an earlier treatment (43).

Patients with stage III CC benefits from adjuvant chemotherapy with improved OS and CFS. Patients with stage II and adverse prognostic factors such as bowel perforation, high-grade tumors, T4 tumors, or lymph vascular invasion, probably benefit from adjuvant therapy (44). In high-risk stage II CC patients, adjuvant treatment with a single-agent fluoropyrimidine therapy (5-FU), reduces the risk of death by 3-5%, while in stage III disease 5-FU monotherapy reduces mortality by 10-15%. The addition of oxaliplatin to 5-FU therapy provides a further 4-5% improvement in survival (26).

# Short-term outcomes

The occurrence of postoperative complications after CC surgery remains common and clinically important. Beyond increasing short-term morbidity, complications are associated with inferior overall and disease-free survival (45). Based on their nature, postoperative complications can be divided into surgical and medical complications.

Surgical procedures are intended to save lives but can cause substantial harm and suffering to patients due to postoperative complications. Even though the quality of surgical care has gained interest in the last decades there is still no consensus how to define and grade surgical complications.

In 1992, Clavien et al., proposed a classification system consisting of four severity grades for surgical postoperative complications. Complications were defined as "any deviation from the normal postoperative course"(46). The original system was later revised in 2004 by Clavien and Dindo who created the Clavien-Dindo classification system (47)(Table 2).

**Table 2**. Clavien-Dindo Classification

| Grade | Definition |
|---|---|
| I | Deviation from normal post-operative course without the need for pharmacological and surgical, endoscopic, and radiological interventions. |
| II | Requiring pharmacological treatment with drugs other than allowed for grade I, including blood transfusion and total parenteral nutrition. |
| IIIa | Requiring surgical, endoscopic or radiological intervention under local anesthesia |
| IIIb | Requiring surgical, endoscopic or radiological intervention under general anesthesia |
| IVa | Life-threatening complication requiring intensive care unit management single organ dysfunction |
| IVb | Life-threatening complication requiring intensive care unit management multiorgan dysfunction |
| V | Death of a patient |

**Note:** Modified Clavien-Dindo Classification according to type of therapy required to manage complication. Dindo et al. 2004 (47).

The high risk of postoperative complications in CC surgery is high regardless if the procedure is performed electively or emergently.

Approximately 30 % of patients undergoing elective CC surgery and up to 50% of patients undergoing emergency resections, experience postoperative complications (48). The difference in the proportion of complications is likely explained by the fact that patients in need of an emergency procedure are older, have a more

advanced stage of disease, more frequently suffer from co-morbidities and are in a poorer physiological condition.

The severity of postoperative complications after CC surgery varies from mild complications such as urinary tract infection treated with antibiotics, to severe complications like anastomotic leakage (AL) necessitating reoperation and possibly care at the intensive care unit (ICU). For the hospital, postoperative complications are a financial challenge and for the individual patient, complications results in suffering. Furthermore, for the individual patient, complications can hinder administration of proper adjuvant chemotherapy and increase the risk of death.

## Medical complications

Postoperative medical complications are common following major abdominal surgery, influenced by age, comorbidity, obesity, sex, malignant disease and malnutrition, and are associated with prolonged length of stay, increased readmission, and inferior long-term outcomes (49). Reported proportions of complications vary between studies, with the mix of patients, the surgical approach and the definition of complications.

In a large population-based study, Tevis et al. reported medical complications within 30-days after CC surgery as common, after both elective and emergency CRC procedures, with overall complications of 27-35% (50). Pulmonary complications, including pneumonia occurred in 3–6% of patients, while urinary tract infections were reported in 4–7% of patients. Deep venous thrombosis and pulmonary embolism occurred in 1–3% of the patients despite routine of thromboprophylaxis. Cardiac complications, including acute cardiac insufficiency, were reported in approximately 2–5% of patients, particularly among patients with pre-existing cardiovascular disease. Neurological complications, such as stroke were rare, <1%, whereas postoperative delirium is common in elderly patients in the emergency settings and is associated with prolonged hospitalization and increased short-term mortality.

Overall, emergency CC surgery carries a high burden of postoperative medical complications, contributing significantly to early morbidity and mortality. These findings underscore the importance of structured perioperative care and the importance of complication preventing complications.

# Surgical complications

## Postoperative ileus

The definition of postoperative ileus varies considerably across the literature but is a well-recognized contributor to postoperative morbidity following CRC surgery. Reported definitions of postoperative ileus vary widely, both in the time threshold used, ranging from 24 hours to 5 days, and in the the included clinical features. Clinical features includes abdominal distension, nausea, lack of flatus, and delayed bowel movements. Reported incidence of postoperative ileus ranges from 5.3% to 24% (50). Postoperative ileus is associated with delayed initiation of oral intake, prolonged hospital stays and reduced patient satisfaction. ERAS protocols, with opioid sparing analgesia, early oral feeding, and early mobilization are associated with faster recovery of gastrointestinal function after CRC surgery (33).

The development of multiple complications is associated with worse postoperative outcomes including postoperative mortality (51). A study on patients who underwent elective colectomy with postoperative ileus, were more likely to suffer from other postoperative complications compared to those who did not develop ileus.

Further, one of the main long-term complications after colon resection is small bowel obstruction (SBO) (52). A Swedish population-based study evaluated the risk of SBO and SBO requiring surgery after CRC procedures, and its association with open surgery and radiotherapy. The study showed that surgical intervention was required in approximately one third of CRC patients who developed SBO. The risk of SBO was highest in the early postoperative period following CRC surgery but remained persistently elevated compared with the general population throughout long-term follow-up.

## Anemia/bleeding

Anemia is one of the warning signs of CC (3). In elective CRC surgery, preoperative correction of anemia preferably with iron supplementation is recommended, to reduce the perioperative risk and need for blood transfusion. In emergency CRC surgery, optimization opportunities are limited and iron substitute not beneficial. The management of patients in need for emergency treatment should be focused on stabilizing patients hemodynamically and blood transfusion should be performed with restrictive indication-based transfusion practice.

In a meta-analysis by Amato et al., perioperative blood transfusion within one month of curative CRC cancer surgery was associated with a higher risk of recurrence (OR1.4). However, due to heterogenicity among the included studies, the authors could not establish a causal relationship (53). On the contrary, a Swedish study by Mörner et al., showed that blood-transfusion was associated with increased risk of overall mortality but no excess risk of cancer recurrence in patients undergoing stage I-III CC surgery (54).

Postoperative bleeding is a complication following CRC surgery and may necessitate blood transfusion, which may lead to prolonged hospitalization and in some cases the need for reintervention. The Swedish National Guidelines for Colorectal Cancer recommend a restrictive transfusion strategy and emphasize careful intraoperative hemostasis, which aligns with ERAS principles to reduce postoperative morbidity (3, 33).

## Anastomotic leakage

Anastomotic leakage (AL) after CC surgery is a dreaded complication and is associated with substantial morbidity and mortality. AL is defined as the presence of clinical symptoms suggestive of leakage, confirmed by radiological imaging or reoperation (55).

Patient-related risk factors for anastomotic leakage include male sex, ASA class III-IV, comorbidity burden, smoking and hypoalbuminemia. Procedure-related risks include emergency surgery, perioperative blood transfusion and extensive tumor resection. Furthermore, the types of resections performed including transverse resection, left colectomy and subtotal colectomy are independent risk factors for AL (55, 56).

In a nationwide cohort study based on the Dutch Surgical Colorectal Audit including 15,667 patients, AL occurred in 7.5% of patients (56). Patients with AL had a substantially higher 30-day mortality risk, 16.4 % compared with 3.1 % in patients without AL. Independent risk factors for postoperative mortality following AL were age, high ASA score, high CCI score and emergency surgery.

However, it is important to distinguish between patients with colon and rectal cancer, since the risk for AL differs significantly between groups, 11-12% after rectal cancer surgery compared with 3-4% after colon surgery (55). A study from the Danish Colorectal Cancer Group included 9,333 patients undergoing curative CC surgery with primary anastomosis. AL occurred in 6.4% of patients and was associated with an increased risk of 30-day mortality compared with patients without AL (20.9% versus 4.6%).

Identifying patients at increased risk of AL already in the preoperative setting is crucial, as it allows modification of preventable risk factors, consideration of preventive strategies, and intensified postoperative care, ultimately improving outcomes after CC surgery (56).

## Surgical site infection

Perioperative antibiotic prophylaxis is a basic part of prevention of Surgical Site Infections (SSI) in CRC surgery. In 1981, Baum et al. published a systematic review comparing the risk of wound infections for patients undergoing colon surgery with and without perioperative antibiotic prophylaxis and the authors found that the risk of infection was reduced by 40 % with perioperative prophylaxis (57).

SSI is defined by the Center for Disease Control and Prevention as an infection occurring at the site of surgery within 30-days of the surgical procedure (58). Incidence varies between studies depending on patient-related and procedure-related factors. Patient-related risk factors include smoking, male sex, hypoalbuminemia, higher ASA class, diabetes and high body mass index (BMI). Procedure-related risk factors contributing to SSI include emergency surgery, level of perioperative contamination, blood transfusion, open surgical approach and prolonged operating time (58). Current ERAS guidelines recommend administration of a single dose prophylactic antibiotics within 60 minutes prior to incision(23).

## Surgical wound dehiscence

Surgical Wound Dehiscence (SWD), is defined as the partial or complete separation of previously sutured wound edges following surgery, resulting from failure of wound healing (59).

Patient- and procedure-related risk factors for development of SWD include age, hypoalbuminemia, steroid use, obesity, diabetes, smoking, anemia and chronic pulmonary disease as well as emergency procedure, SSI, extensive operation time and malignancy-related procedures (60). Interestingly, surgeon-related factors, such as technical skills and level of experience, have been shown to be of stronger statistical significance than patient-related risk factors in acute wound failure. The use of the small-bite technique, achieving a suture-to-wound length ratio of 4:1, has been shown to reduce the risk of SWD (59).

SWD usually occurs during the first 5-8 days after surgery and prompt identification is important to prevent further dehiscence and infection (59). A Danish study by Jensen et al, consisting of a cohort of 14 160 elective CRC patients, showed that SWD occurred in 3.9% of patients. SWD was independently associated with higher 90-day mortality and reduced 5-year survival rate, as well as an increased risk of later incision hernia repair (60).

Prevention and early detection of SWD is essential, since it is associated with significant impaired short- and long-term outcomes for patients with CRC.

## Stoma-related complications

Stoma formation is common in the management of CRC, particularly in the emergency setting, where patients present with perforation, obstruction, or are physiologically unstable and primary anastomosis is considered unsafe. Although it can be lifesaving, stoma formation is associated with a substantial risk of postoperative complications, reported to range from 21-70% depending on stoma type and patient-related factors (61). Patient-related factors that increase the risk of stoma-related complications are emergency surgery, obesity, malnutrition, diabetes, high dose steroids, and lack of preoperative stoma site marking (3). Early complications,

occurring within 30-days after stoma formation include necrosis, retractions, mucocutaneous separation and high-output stoma-related fluid loss. Late complications include parastomal hernia, prolapse, stenosis, peristomal skin disease and stoma retraction. Awareness of these risks is essential to optimize the perioperative planning and follow-up, especially after emergency setting where preparation and site marking may not be feasible.

In summary, postoperative complications after CC surgery are common with both medical and surgical events. These complications are strongly associated with increased short-term mortality and reduced long-term survival. Prevention, early detection, and structured postoperative care are therefore critical components of high-quality CC treatment.

# The Specimen

The quality of the surgically resected specimen after CC surgery is a determinant of the pathological staging of cancer, and consequently the prognosis as well as the decision to offer the patient adjuvant chemotherapy.

High-quality CC surgery aims to achieve *en bloc* removal of the tumor-containing bowel segment to ensure comprehensive clearance of regional lymphatic tissue. CC is classified as high-risk tumor when at least one of the following pathological risk factors listed below is present:

- Less than 12 examined lymph nodes
- Ratio of positive lymph nodes to total examined ≥ 0,33
- Low tumor differentiation
- Lymph vascular invasion
- Extramural vascular invasion
- Vascular invasion
- Perineural invasion
- Tumor perforation
- Emergency surgery with or without perforation
- Positive CRM
- $R_1$ resection
- Tumor budding
- Elevated postoperative CEA

Low-risk tumor is defined as disease in which none of the above risk factors are identified (3).

Among these established histopathological high-risk factors, lymph node yield and resection margin status are directly influenced by surgical quality, reflecting both the extent and precision of tumor resection.

## Lymph node yield

The importance of removing colon with its adjacent lymph nodes was described already in 1909 by Jamieson and Dobson (62). Lymph node yield is one of the crucial factors to determine the risk of recurrence and the need for adjuvant chemotherapy treatment for patients with CC (20). The specimen should include a minimum of 12 lymph nodes to enable adequate determination of the N-stage (3).

According to the 2024 Swedish National Quality Report for CC, more than 95% of patients undergoing surgical resection with a specimen containing at least 12 lymph nodes, which can reflect a high standard of the oncologic surgical quality (20). Several studies have demonstrated an association between survival and the number of harvested lymph nodes (63). One proposed explanation for this observation is that a low lymph node yield may lead to under-staging and patients with node-metastases can be misclassified as node-negative (63). Tumor deposit and Extramural Vascular Invasion (EMVI) have been shown to be stronger adverse prognostic factors, both being associated with higher risk of distant metastases than lymph node involvement alone (3).

## Resection margin

The R classification describes the presence or absence of residual tumor at the tumor resection site. $R_0$ is defined as no residual tumor in the resection margins of the specimen. $R_1$ resection is the presence of microscopically positive margins, indicating residual cancer cells at the surgical cut edge in the specimen, despite removal of the entire visible tumor. $R_2$ resection means that macroscopic visible residual tumor remains in the patient after surgery (64). The pathologist measures the distance between the mesenteric resection margin and the tumor in millimeters, determining the radicality.

Achieving $R_0$ resections is the aim for curative surgery according to the Swedish National Guidelines for Colorectal cancer (3). A $R_1$ resection is regarded as an oncologically non-radical resection and represents a negative prognostic factor associated with increased recurrence risk and reduced survival. A UK study of patients undergoing elective and emergency CC resection, reported an overall recurrence rate of 18.9% following $R_0$ resections and 55.5% after $R_1$ resections. Furthermore, patients with $R_1$ resections demonstrated significantly shorter OS and CFS compared with those who underwent $R_0$ resection (65). Consequently, these patients should be considered for additional treatment at the MDT (3).

The circumferential resection margin (CRM) is defined as the shortest distance between invasive tumor and the non-peritonealized radial resection surface of the surgical specimen (65, 66). In CC, the cecum, transverse colon, and sigmoid colon are covered by peritoneum, therefore, lack a circumferential radial margin along most of their surface. Consequently, CRM assessment in these segments refers specifically to the mesenteric resection surface, which is the non-peritonealized

outer dissection surface created during surgical mobilization of the bowel and its mesentery.

R status, CRM and lymph node yield are surgical quality indicators influencing the oncologic outcomes after CC surgery.

## Short-term survival

Postoperative mortality is an important quality indicator for surgical care and CRC is associated with a significant postoperative mortality ranging from 4 to 10% (67). The 30-day postoperative mortality is commonly used as a standard short-term outcome variable that reflects the immediate surgical risk.

However, a study on 21 482 pancreatectomies reported an unadjusted 30-day mortality rate of 3.7% which doubled to 7.4% at 90-days (68). The 90-day mortality has been suggested to capture more of a true postoperative mortality rate after major surgeries with an expected prolonged recovery period. Studies comparing 30-day and 90-day postoperative mortality after CRC surgery are limited. This question is particularly relevant in patients undergoing emergency CC resection since they have higher risk of postoperative morbidity compared to electively resected patients. A large American study on patients undergoing CRC surgery concluded that 30-days mortality underestimate postoperative deaths, with 90-days mortality rate being nearly twice as high, findings consistent with observations from pancreatic surgery, as mentioned above (67).

Emergency CC resections are associated with substantially higher short-term mortality compared with elective procedures. The 30-day mortality has been reported to be 5.6% following emergency surgery, compared with 1.0% after elective resections (3), while the 90-day mortality rises to 8.8% and 1.8% respectively (20).

A Dutch study assessing outcome after emergency CRC procedures performed during weekends found an increased 30-day mortality (OR 1.66 95% CI, 1.10-2.50) and severe complications (OR 1.29, 95% CI, 1.03-1.63) compared with surgery performed on Mondays (69). These findings highlight the risk associated with emergency presentation and potential system-factors, underscoring the vulnerability of these patients.

# Follow up

## Swedish Colorectal Cancer Registry

In Sweden, all diagnosed cancer cases are reported to the National Cancer Registry at the time of diagnosis, since 1958. The registry is maintained by the Swedish National Board of Health and Welfare, which is also responsible for the Cause of Death Register, to which all causes of death are submitted (70). These national registries form the basis for epidemiological monitoring and follow-up of cancer outcomes in Sweden.

In 1995, the Swedish Colorectal Cancer Registry (SCRCR) was established as a nationwide prospective quality register, initially encompassing patients with rectal cancer (71). In 2007, the registry was expanded to include patients with CC and currently achieves a national coverage of 98.5% of patients diagnosed with CC. The SCRCR is considered to be a reliable registry for assurance of quality and reliable for research. The aim of the registry is to monitor and improve care for patients with CRC, to enable systematic evaluation of short- and long-term outcomes, to perform interregional comparisons and support clinical research.

The SCRCR collects several variables including the treating hospital, patients' demographics and tumor characteristics, diagnostics, treatments and postoperative morbidity and mortality. Furthermore, survival and recurrence are recorded at 3 and 5 years after diagnosis.

However, the registry has several limitations that should be considered. Procedure data are recorded by the operating surgeon, and follow-up registration varies between hospitals, where registration may be performed by a surgeons, nurses, or administrative staff. This variability may introduce registration errors, however, the impact of such errors is likely minimal given the large sample size. Furthermore, missing data do occur mostly due to lack of registrations.

Validity of the SCRCR show that the registry has a completeness of 98-99% and high validity with about 90% agreement between data and source documents (71). Histopathology variables demonstrate high validity, while detailed recurrence variables and postoperative complications show lower accuracy, reflecting registration challenges and variation in documentation. Overall recurrence is reliably captured, but specific recurrence types and details regarding complications are often underreported, something that likely stems from variable documentation and unclearly applied definitions (72).

# Follow-up

Since the 1990s there has been a debate concerning the potential benefits of follow-up of patients after radically resected CRC. Systematic reviews have concluded follow-up to be valuable for detection of recurrent disease and enabling intervention, which may allow for curative treatment and improve patients long-term survival (73). Recurrence of CC commonly occurs within 3-5 years after the primary surgery. In 98-99 %, recurrence present as extracolonic disease (74). Early detection of recurrence can increase curative surgical resection, and lead to improved survival. CT has emerged as the standard modality for imaging surveillance. In combination with CEA, CT is useful for detection of recurrent disease (75).

**Table 3.** Studies investigating follow-up after colorectal cancer surgery

| Study/Author | n | Follow-up groups | | Main conclusion |
|---|---|---|---|---|
| **GILDA**<br><br>Rosati et al. (77) | 1 228 | I. Minimal | OV and CEA at every 4 months until 60 months<br>Colonoscopy years 1 and 4<br>Liver UL at months 4 and 16 | Increased DFS<br>No difference in OS |
| | | II. Intensive | OV, CEA and CA19-9 at every 4 months until 60 months<br>Colonoscopy yearly until 5 years<br>Chest X-ray yearly until 5 years<br>Liver UL at months 4, 8, 12, 16, 24, 36, 48, 60 | |
| **FACS**<br><br>Primrose et al. (76) | 1 202 | I. CEA | CEA every 3 months until 2 years and then every 6 months for 3 years | Higher rates of surgical treatment of recurrence in groups I and II.<br>No difference in OS |
| | | II. CT | CT chest, abdomen and pelvis every 6 months until 2 years and then yearly for 3 years | |
| | | III. CEA + CT | As in groups I and II | |
| | | IV. Minimal | Follow-up on reported symptoms.<br>CT chest, abdomen and pelvis on request | |
| **COLOFOL**<br><br>Wille-Jørgensen et al. (34) | 2 509 | I. HFO | CT and CEA at 6, 12, 18, 24, and 36 months | No difference in OS |
| | | II. LFO | CT and CEA at 1 and 3 years | |

**Note** n, number of included patients. CEA, Carcino Embryonic Antigen. CT, Computed Tomography. HFO, High Frequency Follow-up. LFO, Low Frequency Follow-up. OV, Office Visits. UL, Ultrasound. DFS, disease free survival. OS, overall survival.

The effect of follow-up for patients after CC surgery has been evaluated in several randomized controlled trials, see Table 3 (34, 76, 77).
None of these trials demonstrated a survival benefit with high frequency follow-up. The Swedish national follow-up program for radically resected CRC is therefore based on the Swedish Danish randomized multicenter trial, COLOFOL, which showed that high frequency follow-up did not improve OS or CFS in patients radically resected for stage II-III CRC. As a consequence, the Swedish National Guidelines recommends a low-intensity strategy consisting of CT imaging and CEA measurement at one and three years after surgery, followed by colonoscopy at three years, and every fifth year until 80 years of age (3).

# Long-term outcomes

## Metastases

CC can disseminate through several pathways. The most common sites for distant metastases include the liver and the peritoneum. Peritoneal spread of tumor is commonly through trans-colic dissemination. In this instance, it is debated whether this should be categorized as distant metastases or as loco-regional recurrence. Additional metastatic routes include hematogenous spread to the lungs, bone and brain, as well as lymphatic dissemination. Metastases may also occur in ovaries and adrenal glands (78).

Recurrence rates are higher in patients operated in an emergency setting compared to elective patients, probably due to lower rate of R0 resections, inadequate lymphadenectomy as well as increased risk of tumor perforation and peritoneal contamination (79).

### Liver metastases

The liver is the most common site for distant metastasis in CRC, due to the venous drainage of the colon into the portal venous system. Liver metastases develop in a substantial proportion of patients with CRC, previous studies suggest that up to 50% of patients with CRC will develop liver metastases during the course of the disease, and that approximately 20-25% present with liver metastases at the time of diagnosis (80). Surgical resection remains as the only treatment with proven curative potential for CRC liver metastases. However, only a minority of patients with liver-limited disease, approximately 10-30%, are considered resectable with curative intent at the time of detection. In selected patients, complete metastasectomy is associated with favorable long-term outcomes, with reported 5-year OS rates exceeding 50% (81).

In a present Danish cohort study, the 5-year cumulative incidence of liver metastasis due to CRC was 19.8% based on register data, whereas manual medical record review indicated a higher incidence of 26.2%, suggesting underreporting of metastatic disease in national registries (81). Synchronous disease accounted for 68.9% of CRC liver metastasis patient, indicating that most liver metastases were present at the initial CRC diagnosis.

For selected patients, treatment of CRC liver metastases may consist of combination of local ablative therapies and liver resection or ablative therapies alone.

### Locoregional recurrence

Local recurrence of CC is defined as the presence of tumor regrowth within the abdominal cavity, arising from the primary colon tumor, excluding metastases to the liver or lungs, but including peritoneal recurrence (3).

Although surgery is intended to be the curative treatment of CRC, approximately 20% of patients experience recurrence of disease (82). Over the recent decades, the risk of recurrence after CC surgery has declined. In a Danish population-based study including three calendar periods, a decline in recurrence from 25.5% in the first period to 14.6% in third period was demonstrated (82). This reduction may be attributed to screening, improved staging and surgical techniques, and a more thorough pathological evaluation. Reliable knowledge of recurrence risk is essential in decision-making regarding adjuvant therapy.

Local recurrence should when possible be resected when possible, and follow the same oncological principles as primary tumor resection (3). However, resection of recurrent disease is technically more challenging due to adhesions and altered anatomy, which reduces the likelihood of achieving a $R_0$ resection in patients with local recurrence compared with primary resections.

The risk of local recurrence or lymph node metastasis is approximately 5% in patients with one high-risk feature and increases to 23% in patients with two high-risk features (83).

## Survival

In cancer treatment evaluation, OS is considered the gold standard endpoint, because extending patients survival is the fundamental aim of oncologic therapy (84). OS is defined by the time from diagnosis or initiation of relevant treatment to death by any cause. The primary strength of OS lies in its objective and well-defined measurement. However, OS requires large populations and may be less appropriate in slowly progressing diseases with long expected survival. In such a setting, the introduction of new and alternative treatments during follow-up can result in crossover effects that hide actual differences. Furthermore, non-cancer related deaths will influence OS and can potentially lead to false conclusions (85).

Disease-free survival (DFS), denoted in this thesis as cancer-free survival (CFS), is defined as the time from curative treatment to the development of disease/recurrence or death (84).

Despite the improved survival rates, the clinical presentation of CC remains a strong determinant of surgical outcome. Patients presenting emergently are

generally older, have a higher burden of comorbidity and have more advanced tumors, compared to patients undergoing elective surgery.

Emergency presentation is consistently associated with higher proportion of postoperative morbidity, including both surgical and medical complications, as well as increased 30-day morbidity and mortality. These early adverse events are clinically important, as postoperative complications have shown to negatively influence OS and CFS (6, 86, 87). A study by Mc Ardle et al., in Scotland on 3 200 patients with CRC showed an OS at 5 years of 57.5% in patients after curative elective resections and 39.1% after curative emergency surgery (105).

OS is defined as the time from diagnosis or treatment to death from any cause, whereas relative survival (RS) compares the observed survival of patients with the expected survival in a matched general population, thereby estimating disease specific excess mortality without requiring cause of death information (88).

In Sweden, the national 5-year follow-up coverage for CC was 85% in 2024 (20). Furthermore, the 5-year relative survival for CC has improved from 39.6% in the 1960s to 57.2% in 1995 to 65-70% in the 2010s (89). More resent reports from the SCRCR, state a 70% 5-year OS for patients with CRC, potentially reflecting improvements in early detection, surgical quality, perioperative care and adjuvant therapy (90).

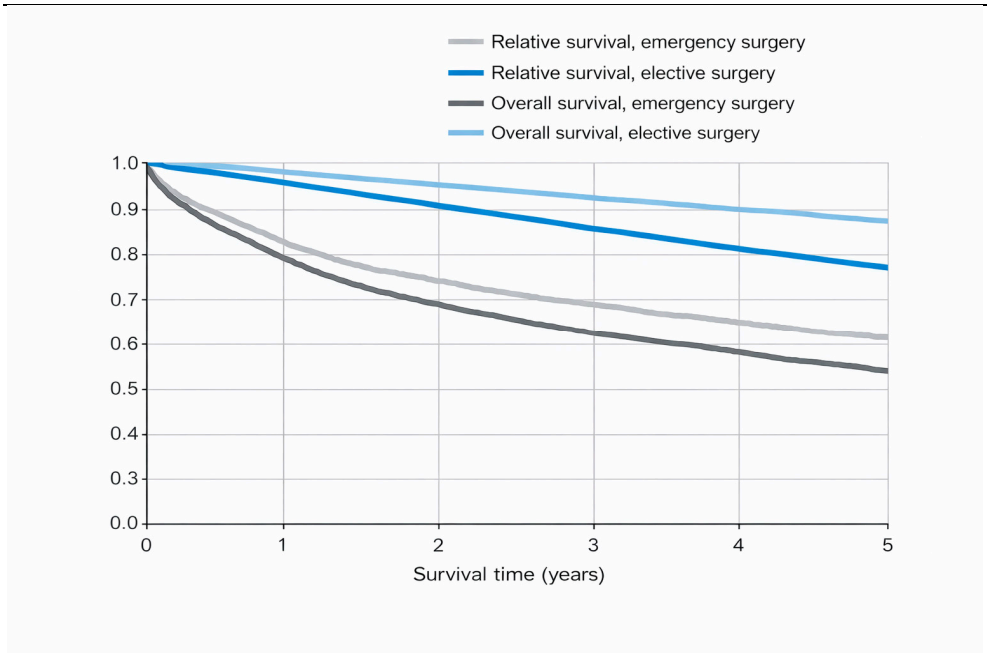


**Figure 3.** Overall and relative survival stratified by emergency versus elective surgery among patients diagnosed with CC in Sweden between 2008 and 2024.
Relative survival represents survival adjusted for expected mortality in the general population. Figure reproduced with permission from SCRCR (20).

# Factors affecting postoperative outcomes

## Patient-related factors

Patient-related factors are critical determinants of the higher morbidity and mortality observed after emergency CC surgery compared with elective procedures. Advanced age is a well-established non-modifiable risk-factor, and several studies have demonstrated that patients aged 70 or older have increased postoperative morbidity and mortality (91). In addition to age, preoperative physiological status, as classified by the ASA, is a strong predictor for postoperative outcomes, with ASA class III or higher associated with an elevated risk. This increased vulnerability is often driven by underlying comorbid conditions, particularly neurological comorbidity, cardiorespiratory disease, renal insufficiency and diabetes mellitus (92).

Nutrition status is an important modifier for surgical risk. Low preoperative serum albumin levels, a marker for malnutrition and systemic disease, are strongly and independently associated with increased rates of surgical site infections, sepsis, and overall postoperative mortality (93). A study on a total of 54 215 noncardiac surgical procedures, demonstrated serum albumin concentration as a better predictor of surgical outcome than many other preoperative patient characteristics. In 2023, a systematic review, including more than 230 000 patients with CRC, demonstrated that preoperative hypoalbuminemia is significantly associated with increased postoperative morbidity, higher rates of surgical complications, and prolonged length of hospital stay. In contrast, hypoalbuminemia was not associated with 30-day mortality (19).

Taken together, these patient-related factors can partly explain the poorer outcomes observed after emergency CC surgery, highlighting the importance of careful risk stratification and perioperative optimization.

## Surgeon-related factors

In the early 20th century, surgeons performed a wide spectrum of procedures and there was limited differentiation between specialties, evolving in the last decades towards surgical specialization and evidence-based practice (94). Advances in

surgical technology, anesthesia, and structured training programs have transformed the surgical practice and enabled surgeons to focus on more specific areas of expertise. This has led to improved patient outcome and the development of surgical subspecializations such as thoracic, gastroenterological, and plastic surgery. Alongside these developments, in the 1970s interest emerged regarding impact of surgical volume, suggesting that both surgeon- and hospital experience may influence the patient's postoperative outcome and overall quality of care (95, 96). More recently, in 2017 Wallis et al., published a study suggesting that surgeon gender may have an effect on surgical practice patterns and also a significant influence on patients postoperative outcome (97).

In Sweden, surgical practice has evolved in parallel with global advances in surgery, gradually transitioning from a predominantly general discipline to an increasingly subspecialized field. This shift accelerated during the 1970s when technological innovations alongside structured residency programs changed the clinical organization and surgical education (98). Nevertheless, certain fields, including colorectal- and acute care surgery remain under the domain of general surgery, and there is an ongoing debate regarding optimal structure of surgical training to maintain a broad surgical competence. In parallel, national policies have since 2015 been promoting centralization of surgery, with an intention to improve quality of care (99).

## Subspecialization

Patients requiring emergency CRC surgery commonly present with diverse and complex pathology, requiring broad oncological skills and advanced operative skills. In contrast to the United States, where there is an established subdivision into Acute Care Surgery (ACS) and Colorectal Surgery (CS) by structured fellowship training programs, Sweden has adopted a different model. Neither acute care surgery nor colorectal surgery are formally recognized as distinct surgical specializations. Instead, the Swedish Surgical Society has developed a structured national surgical emergency training course to prepare surgeons for senior on-call duty (*Bakjoursskolan*, a Swedish national training program).

In Sweden, CSs are board-certified general surgeons who predominantly work at a colorectal unit, with sustained clinical and operative management of patients with colorectal disease. The European Society of Coloproctology offers an European board examination; this certification is not required for clinical practice of colorectal surgery in Sweden. Instead, subspecialization is defined by continuous clinical engagement and operative experience. To support high standards of care, the Swedish Surgical Society provides advanced national courses in colorectal surgery.

Subspecialization in colorectal surgery has been associated with improved outcomes in elective CC surgery, with lower morbidity and mortality reported when procedures are performed by CS compared with Non-Colorectal Surgeons (NCS) (100). These benefits are generally attributed to higher procedural volumes and greater familiarity with oncological principles. However, such findings may not be

directly applicable to emergency CC surgery, where patients often present with obstruction or perforation and significant physiological compromise.

Emergency CC surgery is performed during on-call hours by board-certified surgeons from different surgical specialties. ACS are surgeons that primarily work in the emergency surgical units and manage a broad caseload of urgent surgical conditions. During on-call duties, emergency CC surgery may also be performed by board-certified surgeons from other surgical specialties, such as vascular or upper gastrointestinal surgery. Hench, in Sweden in 2024, a relatively large proportion of emergency procedures were performed by CS, with 82% carried out during on-call hours between 0600 PM and 0700 AM (20).

Emergency CC surgery is complex, and surgeons must balance the need to minimize postoperative morbidity and mortality in physiologically unstable patients with the requirement for high-quality oncological resection, raising the question of whether subspecialization influences outcomes.

## Surgical and hospital volume centralization

Surgical volume may be considered at either surgeon level or hospital level. It typically refers to the annual number of specific procedures performed by an individual surgeon or within an institution. Surgeon volume is generally used as a proxy for individual experience and technical familiarity with a procedure, whereas hospital volume reflects institutional experiences, including multidisciplinary support operative infrastructure, and ability to manage complications (96, 101).

In 1979, Luft et al., published a study raising the question of whether there is a relationship between hospital surgical volume and patient mortality (95). In the analysis, hospitals performing more than 200 procedures per year across various surgical fields, had lower mortality rates compared to hospitals with lower annual volume. Subsequent studies have confirmed the association between hospital volume and surgical outcome (96, 102-105).

Two main hypotheses have been proposed to explain volume-outcome relationships. The “practice makes perfect” hypothesis suggests that higher surgical volumes lead to better outcomes through accumulated experience at both the surgeon and team level. In contrast, the “selective referral” hypothesis proposes that hospitals with superior outcomes attract more patients, thereby increasing volume (106). Whether it’s the first hypothesis or the second, in elective surgery high volume hospitals or surgeons or preferably both has proven to result in superior outcomes for patients. More favorable outcomes among patients operated on by high-volume surgeons can possibly be attributed to the accumulated experience which allows for surgeons to minimize technical errors (105). Better outcomes for high volume hospitals can be attributed to a clinical environment that increases the safety around the patients surgical pre-, per- and post-operative care (107).

Current evidence regarding the impact of hospital- and surgeon volume on patient’s outcome after emergency CRC surgery remains conflicting. A study from Hong

Kong by Kwan et al., on emergency colorectal procedures and hospital volume, showed worse hospital mortality after emergency colectomies for high volume hospitals (108). Contrasting this, a Swedish retrospective register study by Bergwall et al. on elective and emergency CC patients, found significantly longer 5-year survival among patients operated on emergently by CS with high annual resection volume (100).

Driven by the evidence that high volume hospitals are associated with improved patient outcomes, Sweden has in the last decades, experienced a national progressive shift toward centralization for cancer surgery. A national investigation into the centralization of surgical care conducted by Rosen et al., concluded that concentrating care improves results for rare as well as common procedures (99). Most studies examining the effect of volume on postoperative outcome, adjust for patients' characteristics, but less often for organizational factors including leadership, staffing, and team stability, which also influence outcomes. These factors may influence outcomes by affecting decision-making, continuity of care, communication, and the ability to manage complications, and their absence may therefore confound observed associations between surgical volume and postoperative outcomes. The use of tools like surgical checklists and adequate staffing, can reduce mortality and complication rates, helping to explain why some low-volume hospitals achieve good outcomes while some high-volume hospitals do not. Rosen et al. concluded that the available evidence was consistent and showed a clear dose-response relationship between surgical volume and outcomes, with higher procedural volumes associated with better results. Based on this interpretation, the report proposed a benchmark of 50-100 procedures per hospital per year and at least 30 annual procedures per provider or team to maintain quality. It was further argued that such volumes could enable shared learning, multidisciplinary expertise, and more efficient use of resource with few demonstrated negative effects. However, these conclusions represent the perspective of a single national inquiry and a report advocating for increased centralization of both highly specialized and broader specialized care in Sweden, while acknowledging the need to balance emergency access and patient travel considerations.

In Denmark, centralization regarding parastomal hernia repairs was introduced in 2010. A study by Helgestrand et al., evaluated the impact of centralizing emergency care for parastomal hernia repairs and found significant improvements in patients' outcomes. Following centralization, reoperation rates after emergency repairs decreased from 44.9% to 23% and mortality from 10.3% to 2% (109).

Similarly, centralization of colorectal surgery in Sweden led to improved quality of resection specimens and a decrease in reoperations and mortality in patients treated for distal sigmoid colonic cancer and furthermore, long-term survival in this group of patients was also improved (110).

A potential concern related to the centralization of CC surgery is that emergency CC resections may be performed by surgeons with limited experience in emergency colorectal procedures. This risk may be particularly relevant in rural areas, where

long distances to hospitals that performing colorectal surgery can delay transfer, and lead to patients presenting with need of immediate surgical intervention. Furthermore, emergency CC surgery is more complex than elective surgery, as patients often present with significant physiological compromise and the operative setting is technically more demanding. However, centralization does not necessarily eliminate this challenge, as colorectal surgeons may also have limited exposure of emergency colon resections. These considerations underscore the need to evaluate surgical organization and training to ensure that surgeons responsible for emergency CC care are trained both in advanced oncological surgery but also in acute surgical management.

Despite extensive investigations of volume-outcome relationships, definitions of surgical volume vary widely between studies and are often based on data-driven cutoffs (i.e. quartiles), or considerations related to local healthcare systems rather than clinically derived thresholds (111). Consequently, reported volume-outcome associations must be interpreted in the context of how volume is categorized and defined in each study.

## Surgeon gender

*"No carpenter, smith, weaver or women shall practice surgery"*

With this decree, King Henry the VIII formally excluded women from surgical practice during the Middle Ages. Historical records reveal that women performed surgical procedures as early as 3500 BCE, illustrating that women have long been part of the surgical profession. Despite this long-standing history, the path for women entering modern surgical practice has been marked by significant challenges, with the most prominent barriers in recent times being limited mentorship and concerns related to work-life balance (112).

In Sweden, Karolina Widerström was the first woman to obtain a medical degree in 1884, followed by Gertrud Gussander, who was recognized as Sweden's first female surgeon in 1912 (Figure 4). Remarkably, Sweden appointed its first female professor of surgery in 2013 at Umeå University, a late progression of women within academic and surgical leadership compared with their male counterparts.

**Figure 4.** Photograph of Gertrud Gussander (1872-1952), Swedens first female surgeon. Gussander completed her doctoral dissertation on gastroptosis – the abnormal downward displacement of the stomach – in 1912 at Lund University. Image used with permission from the Håkan Westling Archives, Lund University Library.

Historically, surgery has been a profession dominated by men. Over the past decades, the proportion of women in surgery has increased but still women represent less than one-third of the surgical workforce worldwide (113). The gender

distribution within surgery varies considerably between regions. In the United States, approximately 40% of residents in general surgery are women, whereas female surgeons only constitute 21% of the surgical workforce in Australia (114, 115). This disparity in gender distributions of surgeons is more accentuated in some African countries, where female surgeons represent one-tenth of the surgical staff (116). In Sweden, the proportion of female surgeons reached 35% of the surgical workforce in 2024 (117). Despite these advancements, women remain underrepresented at senior and leadership levels within surgery (118). These observations underscore that there is a persistent gender disparity within surgery in surgical practice, which raises concerns on structural barriers, workplace culture, and what strategies that are required to achieve genuine gender equality in the field.

Studies report concerns regarding work-life balance and the perception of surgery as being incompatible with a family life as primary reasons for women to avoid a carrier in surgery (119). Additional barriers include the lack of female surgical role models, and the persistence of a "boys club culture" within the profession, both of which contribute to a less inclusive environment for women (120, 121). Considering the potential structural barriers that hinder women from pursuing a career in surgery, it has been suggested that the pool of female surgeons may be a selected group displaying greater expertise, determination and attentiveness than their male counterparts (121). However, there is to date no clear evidence supporting this assumption (118).

Research examining the impact of surgeon gender on the patient's postoperative outcome is a relatively new and rapidly developing scientific field, as suggested by the observation that most studies have been published during the last decade. Despite the increased scientific interest, the current body of literature is limited, and the findings are inconsistent across studies. Several large-scale analyses have reported a relationship between surgeon gender and postoperative outcomes, while other studies observed no measurable effects, prompting for a continued debate, summarized in Table 4.

The most influential study examining surgeon gender and outcomes was the first study by Wallis et al. published in 2017 (97). This study demonstrated that patients treated by female surgeons had lower 30-day postoperative mortality after elective procedures compared to patients operated by male surgeons. No such differences were identified after emergency procedures. A subsequent follow-up study by the same authors assessed the 90-day and 1-year postoperative outcomes (122). The authors adjusted for patient's comorbidity, surgeon procedure volume, case mix, hospital and anesthesiologist covariates, and found that patients operated on by female surgeons had better postoperative outcome. Furthermore, the authors found that the survival benefit was even greater when female patients were operated by female surgeons (97, 122).

A Swedish study published by Blohm et al, in 2023 concluded that patients who underwent elective cholecystectomy and were operated on by male surgeons had significantly more surgical complications, but such a difference was not observed

after emergency procedures (123). In this study, patients operated on by female surgeons had significantly longer operative times, which the authors interpreted as reflecting greater perioperative caution, leading to significantly lower amount of complications.

In a dataset encompassing almost 5 million procedures, surgeon gender was associated with postoperative outcome in unadjusted analysis, but after propensity score matching, female surgeons had a small statistical association with lower mortality and complication rates, but not readmissions (124). Another metanalysis by Saka et al., comparing 5.4 million procedures concluded lower postoperative mortality rates for patients operated on by female surgeons compared to male, but no difference in postoperative complications or readmissions (125). Furthermore, Heybati et al., reported an improved 1-year survival at home for patients operated on by female surgeons, irrespectively if surgery was elective or emergency (126).

In contrast, several studies have shown no association between surgeon gender and patients' postoperative outcomes. A Japanese study on right-sided hemicolectomies in 58 000 patients, demonstrated no difference in short term severe complications or mortality between patients operated on by male or female surgeons (127). A meta-analysis with more than 1 000 000 procedures performed in North America detected no difference in intraoperative or postoperative mortality between patients treated by male or female surgeons (128).

This observation was consistent with a study conducted in three states in the U.S., which after patient matching reported comparable rates of complications, hospital stay and mortality between patients operated on by male and female surgeons (129). A recent meta-analysis by Caturegli et al., similarly reported no significant gender-related differences across a broad range of elective procedures (130). Likewise, studies by Okoshi et al. and Tsugawa et al., showed no difference between surgeon gender and postoperative mortality (131, 132).

The existing literature on surgeon gender and postoperative outcomes is characterized by substantial heterogeneity in surgical procedures, study populations, and clinical settings. However, an important limitation of this body of evidence is that it largely consists of retrospective and registry-based studies, which restricts the ability to draw causal inferences. Consequently, observed associations should be interpreted with caution, and conclusions regarding underlying mechanisms or context-specific effects cannot be definitively established based on the current evidence.

**Table 4.** Studies investigating the influence of surgeon gender on patient outcomes.

| Author | Study type | n | Outcomes | Main findings |
|---|---|---|---|---|
| Wallis et al. (97) | PB | 104,000 | Complications, readmissions and 30-day mortality | FS had lower adjusted risk of mortality. Similar readmission and complication rates, after surgeon–patient matching. |
| Wallis et al. (122) | PB | 1 165 711 | Complications, mortality and readmission rate at 90 days and 1 year | FS associated with lower risk-adjusted adverse outcomes at 90-days and 1 year. |
| Blohm et al. (123) | PS | 150 000 | 30-day morbidity and Mortality | MS had more complication and bile duct injuries. Similar 30-day mortality between FS and MS |
| Scali et al. (124) | RCS | 4 882 784 | Complications, in-hospital mortality and readmission | FS had lower mortality and complication rates. Readmission rates were similar. |
| Saka et al. (125) | SR, MA | 5 400 000 | Complications, in-hospital mortality and readmission | FS had lower mortality for both emergency and elective procedures. Complication and readmission rates were similar. |
| Heybati et al. (126) | RCS | 1 165 711 | DAH | Patients of FS experienced a higher number of DAH when compared with MS. |
| Sharoky et al. (129) | RCS | 1 335 000 | Postoperative complications, in-hospital mortality and prolonged length of stay | No difference in mortality and complication or length of stay after matching between patients operated by male and female surgeons. |
| Tsugawa et al. (132) | ROS | 892 187 | 30-day mortality | No significant differences between FS and MS |
| Okoshi et al. (131) | ROS | 149 193 | Short-term complications and mortality | No significant differences between FS and MS |
| Carter et al. (128) | SR | >1 000 000 | Mortality | No difference in mortality between MS and FS. |
| Caturegli et al. (130) | SR, MA | 4 440 740 | Complications, in-hospital mortality and readmission | No association between surgeon gender and early postoperative outcomes in elective surgery. |
| Matsuda et al. (127) | ROS | 58 503 | Short-term complications and mortality | No significant differences between FS and MS |

**Notes.** Studies above dashed line shows favorable outcome for patients operated by female surgeons. Studies below dashed line showed no gender difference.
PB, population based. RCS, retrospective cohort study. SR, systematic review. MA, meta-analysis. ROS, retrospective observational study. n, number of patients. N/A, not available. DAH, days alive at home. FS, female surgeons. MS, male surgeons.

## Definition of gender

In the scientific community, there is a consensus that the meaning of the terms "gender" and "sex" should be distinguished, but these terms are often used interchangeable and sometimes remain undefined in studies. The term sex refers to biological factors, such as reproductive anatomy and hormonal profiles, and is categorized into

male or female (133). Gender, in contrast to the term sex, is socially and historically constructed and it encompasses norms, expectations and identities that shape how individuals are perceived and act within specific cultural contexts (134, 135). Both gender and sex are important considerations in medicine, as sex-related factors may influence disease patterns, while gender shapes communication, decision-making and doctor-patient interaction (136). Greater precision could be achieved by asking participants to self-report both sex and gender, thereby improving both validity and interpretability of findings.

## Gender and surgeon skills

Surgical technical performance is a combination of surgical knowledge, judgement and dexterity (137). Manual dexterity is the ability to coordinate hand and finger movements. Dexterity particularly requires muscular and neurological functions to produce small precise movements safely to be performed in surgical procedures (138).

Various studies have investigated if technical skills differ based on the gender of the surgeon. In 1985, 141 surgical residents were evaluated over the course of 1 480 procedures, using neuropsychological assessments of visuospatial ability, psychomotor performance and stress tolerance (139). Female residents demonstrated superior academic achievement compared with their male colleagues, but scored less well on visuomotor task, a task that according to the authors was a predictor of operative skill. Other evidence contrasts this interpretation. In veterinary training, students participating in hands-on suturing practice achieved significantly higher test scores compared with those using online instructions solely, and female students showed overall statistically higher performance scores than their male counterparts (140). A systematic review of 18 studies found that male medical students often outperform female surgeons in early surgical skills training, but gender differences disappeared at the resident level (141). The authors suggest that practice reduces early performance differences and that the learning environment, including repeated practice, may play a critical role in explaining the initial gender-based disparities in technical performance. Furthermore, the authors added that observed differences are not fixed traits but can be shaped by pedagogical design, highlighting the importance of considering contextual factors when interpreting performance outcomes.

Physical components of technical performance have also been examined (138). A study comparing manual dexterity and hand-grip-strength show that male surgeons exhibit greater grip strength, whereas female surgeons tend to perform better on measurements of fine motor dexterity, but surgical specialization was not correlated to neither hand-grip-strength nor manual dexterity. Further, subjects with small glove sizes were associated with better manual dexterity compared with subjects with large glove size.

These findings suggest that baseline differences in psychomotor attributes may exist between genders. Importantly, these attributes are modifiable through training and should not be predeterminant determinants of surgical capability.

## Gender and surgeon personality

Personality has been proposed as a factor contributing to variations in surgical decision-making, particularly in high-risk situations where no established gold standard exists. In an international survey using hypothetical rectal cancer scenarios together with the Big Five Inventory, researchers examined whether surgeon personality influences anastomotic decision-making (142). The Big Five is a hierarchical organization of personality traits that includes five basic dimensions Extraversion, Agreeableness, Conscientiousness, Emotional Stability versus Neuroticism, and Openness to experience (143). The survey concluded that personality traits function as an independent predictor of surgical choices, although no single trait consistently explained all choices (142). Gender and experience were further shown to interact with personality, younger female surgeons were more influenced by recent criticism related to anastomotic leakage whereas older surgeons tended towards a greater risk-taking in emergency scenarios. In conclusion, the authors suggested that individual personality profiles and risk perception may shape surgeons' operative strategy, such as to perform an anastomosis versus a stoma.

A recent Swedish online survey assessed gender-based disparities in personality traits by sending a survey to general surgeons in Sweden (144). Authors concluded that female and male surgeons have different personality profiles. Female surgeons scoring significantly higher in agreeableness, extraversion, conscientiousness and neuroticism compared with their male colleagues.

## Physician gender across medical specialties

Looking beyond surgery, research on provider gender related outcome in internal medicine have shown that female and male physicians practice medicine differently. Multiple studies conclude that female physicians are more likely to use and follow guidelines, engage in effective communication and provide patient-centered care. Female practice patterns are typically associated with improved patient outcomes, including better quality of life, lower proportions of readmissions and reduced mortality, in comparison with care provided by their male counterparts (145-148).

In orthopedic surgery, lower overall number of adverse events was reported after total hip arthroplasty for patients operated by female surgeons. However, no significant differences in outcomes were observed between patients operated on by male and female orthopedic surgeons (149).

In a study assessing patients' satisfaction in primary health care, authors found that patients reported higher satisfaction when treated by female physicians (148). This study, which was based on videotaped encounters, revealed no significant difference in the length of the consultations. However, female physicians engaged more frequently in preventive health discussions and demonstrated more distinct communication behaviors, which the authors suggest can partly explain the higher satisfaction ratings.

Not all findings favor female physicians. An analysis of online patient reviews in urogynecology revealed that female surgeons received lower satisfaction scores compared to their male colleagues (150).

Taken together, research beyond the surgical field, indicates that gender-linked differences in clinical practice do exist, and in some context may influence patients' outcomes. However, these findings are not uniform across specialties, emphasizing the importance of examining gender effects within specific environments, rather than assuming a universal pattern. Further studies should focus on exploring how institutions and professional norms, communication practices, and workload structures interact with gender to shape clinical decision-making and outcomes.

## The science of gender

In psychological science, the magnitude of gender differences remains an unsettled issue. Research in the 1970s often emphasized behavioral disparities between men and women in decision-making. This perspective was challenged by Hyde et al., with the *Gender Similarity Hypothesis*, arguing that women and men are more alike, differences are either trivial or small and only a minority of traits show moderate to large differences (151). In contrast, a meta-analysis of 150 studies on risk-taking and gender differences revealed that men on average engage in higher levels of risk-taking compared to women across a variety of behavioral contexts (152). Eagly et al., later proposed an integrated view, arguing that observed gender differences are shaped by methodological choices and context. They contended that combining multiple gender-related traits increases statistical power and produces larger effect sizes. Although differences in individual traits are often small, aggregating traits can reveal overall differences (153).

The interaction between stress and decision-making have also been explored experimentally. An investigating found males to be more prone to risk-seeking behavior under stress, whereas women tend to become more risk-averse under stress (154). However, another study demonstrated that cortisol responsiveness, rather than gender per se, predicted risk-taking under stress, indicating that physiological stress responses may override gender patterns (155).

This raises the possibility that individual differences in stress reactivity could influence clinical decision-making in high-pressure situations, potentially contributing to variation in patient management and outcomes.

# Aims

The overall aim of this thesis was to analyze the effect of surgeon-related factors on patients short- and long-term outcome after emergency CC resections.
The specific aims were to:

- Investigate the effect of surgical specialization and surgeon resection volume on short-term outcome after emergency CC resections (Paper I).

- Analyze the long-term effect of surgical specialization on patients after emergency CC resections (Paper II).

- Evaluate the effect of surgeon gender on postoperative short- and long-term outcome after elective and emergency CC resections (Paper III).

- Evaluate the effect of surgeon gender on postoperative short- and long-term outcome after emergency CC resections (Paper IV).

# Methods

## Study population

The SCRCR was used to identify all patients who underwent elective and emergency CC resections between January 1, 2010, and December 31, 2020. Patient demographics, clinical characteristics, surgical details and postoperative outcomes were extracted from the SCRCR and provided in coded form.

Patients were included if they met the following criteria:

- Surgical resection for primary CC tumor located between the ileocecal valve and 15 cm above anal verge

Patients were excluded if any of the following criteria were met:

- Appendiceal neoplasm
- Age younger than 18 years
- Resections performed for benign colon disease
- Rectal cancer

A standardized data extraction manual was developed. The manual contained variables and clinical information beyond what could be obtained from the SCRCR, allowing for supplement the registry data with additional information from patients' medical charts. Using the manual, detailed data on patient characteristics, surgical procedures, tumor features and postoperative outcomes were extracted from the medical records (Table 5). The manual included definitions for each variable and was used by all researchers to minimize the risk of information bias during data collection (156). Prior to data extraction, all reviewers received training in the use of the manual. Any uncertainties encountered during the medical record review were flagged and subsequently resolved through joint reassessment with the principal investigator to ensure data consistency and accuracy.

**Table 5.** Patients baseline characteristics and perioperative variables in Paper I-IV

| Category | Variables |
|---|---|
| Demographics | Age, sex, and BM |
| Comorbidity | ASA classification and CCI |
| Surgical data | Surgical approach (open/laparoscopic), timing of surgery (day/night), operative time, urgency (elective/emergency), indication for emergency surgery, responsible surgeon, stoma creation, perioperative bleeding, curative resection |
| Tumor characteristics | Tumor location and TNM |
| Postoperative outcomes | Complications graded by Clavien–Dindo, reoperation, ICU admission, length of hospital stay, readmission, 30-day, 90-day mortality and adjuvant treatment |

**Note:** BMI, Body Mass Index. ASA, American Society of Anesthesiologists. CCI, Charlson Comorbidity Index. TNM, Tumor Node Metastasis. ICU, Intensive Care Unit.

Postoperative complications were registered according to the Clavien-Dindo classification. For Paper I-IV only complications of grades II-V were retrieved from the patients' charts. Patients with uneventful postoperative recovery, including minor deviations not requiring interventions beyond antiemetics, analgesics, electrolytes or diuretics, were classified as having no postoperative complications, as Clavien-Dindo grade I events were considered inherent to CC surgery (46, 157). The occurrence of complications was extracted from the SCRCR and validated by reviewing the patients' medical records.

Night-time surgery was defined as incision time between 17:00 and 07:00 hours. Postoperative management and follow-up were conducted according to local routines based on Swedish National Guidelines for CRC and were determined at MDT, with long-term oncological outcomes recorded.

All surgeons participating in each procedure were recorded, and the most senior surgeon actively involved in the procedure was defined as the responsible surgeon for the operation. Surgical experience was defined as the interval from board certification in surgery to the date of each analyzed procedure.

## Surgeons in Paper I and Paper II

In Paper I and II the responsible surgeons were initially classified according to surgical specialization as Colorectal Surgeons (CS) or Non-Colorectal Surgeons (NCS). The NCS group was further subdivided into Acute Care Surgeons (ACS) and General Surgeons (GS), allowing comparisons between CS, ACS and GS (Figure 5). Analyses were conducted in two steps. First outcomes were compared between patients operated on by CS and NCS. Second, outcomes were compared across CS, ACS and GS.

Surgeons´ median annual CC resection volume was calculated, based on the number of elective and emergency CC resections they performed annually. Elective resections for benign colon disease, appendix- and rectal cancer were excluded.

In Paper I, surgeons were categorized into three annual resection-volume groups based on the median and 75$^{th}$ percentile of their individual annual resection volumes.

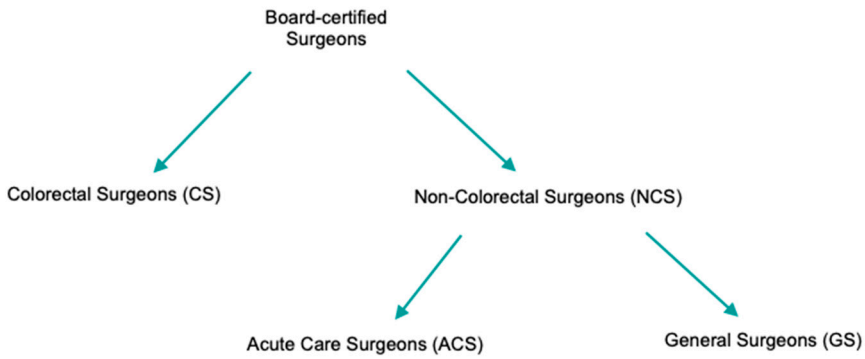


**Figure 5.** Schematic categorization of the surgeons in Paper I and Paper II.

## Patients in Paper I, Paper II and Paper III

The study population consisted of patients undergoing CC resections performed at Helsingborg hospital, a secondary care hospital serving a catchment area of 350 000 residents. The hospital performs approximately 90 elective and 20 emergency CC resections annually (20).

The ASA classification and CCI were selected with the intention to objectively measure the patients perioperative risk. These variables are routinely available at the time of admission in emergency surgical setting. In Paper I-III, surgery performed within 48 hours after acute hospital admission was defined as emergency surgery and all other procedures were classified as elective.

During the study period, SEMS as a bridge to surgery for obstructing CC was not standard practice and patients receiving stents during the study period were therefore not included.

## Patients and surgeons in Paper III

Paper III included both emergent and elective CC resections performed at Helsingborg Hospital between January 1, 2010, and December 31, 2020. Surgeon gender was classified as male or female according to surgeons first name or by personal communication with the research team.

## Patients and surgeons in Paper IV

Paper IV included a multicenter cohort of patients undergoing emergency CC resection at ten hospitals in southern Sweden, comprising university, regional and district hospitals (Table 6). Hospitals were selected based on geographic distance, existing professional contacts and hospital size, and the presence of both male and female surgeons within the surgical staff. The participating hospitals performed 770 (24% of all procedures in Sweden) elective and 130 (27% of all procedures in Sweden) emergency procedures in 2022, according to SCRCR records. The same manual that was used in Paper I-III was applied.

**Table 6.** Classification of participating hospitals by level of care

| Hospital | Level of care |
|---|---|
| Sahlgrenska universitetssjukhuset, Gothenburg | University hospital |
| Länssjukhuset Ryhov, Jönköping | Regional hospital |
| Vrinnevisjukhuset, Norrköping | Regional hospital |
| Helsingborgs lasarett, Helsingborg | Regional hospital |
| Kalmar lasarett, Kalmar | Regional hospital |
| Centrallasarettet Växjö, Växjö | Regional hospital |
| Skaraborgs Sjukhus Skövde, Skövde | Regional hospital |
| Värnamo sjukhus, Värnamo | District hospital |
| Skaraborgs Sjukhus Lidköping, Lidköping | District hospital |
| Höglandssjukhuset, Eksjö | District hospital |

**Note:** Swedish names for the hospitals are used in the table. The categorization of the hospitals level of care is presented as a translation by the author from the Swedish nomenclature used by the National Board of Social Affairs and Health (Socialstyrelsen),

Procedures were classified as elective according to the Swedish National Guidelines, as surgeries scheduled because of logistical factors rather than medical urgency, irrespective of the day or time of operation. Procedures performed after treatment of anemia during admission or following stent as a bridge to surgery were also classified as elective (3). Emergency procedures were defined in accordance with SCRCR criteria as operations performed acutely due to medical indication, regardless of time day. Patients initially scheduled for elective surgery but admitted with emergency symptoms requiring urgent intervention were classified as emergent.

For elective and emergency procedures without resection, the names of all participating surgeons were recorded using a simplified standardized retrospective review. This simplified review included the date of operation, type of procedure, tumor location, stoma formation, and the names of all participating surgeons and was applied to enable calculation of surgeons' annual resection volumes.

In Paper I and III, the ASA classification and the CCI were selected because they proved complementary and an objective assessment of overall perioperative risk and chronic comorbidity burden. However, in Paper I and Paper III, no differences in CCI were observed, and CCI was not associated with outcomes, whereas ASA demonstrated prognostic relevance. Accordingly, CCI was excluded from the analysis in Paper IV.

In Paper IV, surgeon gender was classified as male or female according to surgeons first name or personal communication with the research team.

## Missing data

During data extraction, records containing missing values were flagged and reviewed together with the principal investigator (PI), and the original medical records were revisited to minimize the amount of missing data. The most frequently missing data in Paper I-III, was patients BMI, primarily due to absent height measurements and, to a lesser extent missing weight data. To address this, mean substitution was applied, the mean value of the variable was imputed in place of the missing data point. This method was considered appropriate given the normal distribution of the data and the large sample size, regression imputation was considered an alternative approach.

## Data Protection

In the present studies, only variables necessary to fulfil the research objectives were extracted from patients' medical records, minimizing data collection. The dataset was retained only during analysis and was archived in coded form.

# Ethical principles and approvals

All studies were conducted in accordance with the principles of the Declaration of Helsinki from 1964. In Sweden, patients are informed that data entered national quality registries may be used for research purposes, and therefore no further individual consent from patients were required in this thesis.

Paper I-III were approved by the Swedish Ethical Review Authority (Dnr 2019-04329).

Paper IV was approved by the Swedish Ethical Review Authority (Dnr 2023-03739-01).

The studies are retrospective and observational, based on routinely collected registry and medical record data, with no experimental interventions and no additional physical risk to patients. All data was coded prior to analysis, stored securely and accessed only by the research team. The results are presented in aggregated form, ensuring that neither individual patients nor surgeons can be identified.

Individual informed consent from patients was not feasible, ethical approval was obtained from the National Ethics Authority, which determined the scientific value of the study to outweigh the minimal risk of the patients. Surgeons were not required to provide an informed consent and were not invited to decline participation as this was not requested by the ethics authority.

CC resection, particularly in the emergency setting, is associated with high morbidity and mortality in comparison with other types of surgery and understanding how patient's outcome can relate to surgeon-related factors is of clinical and societal relevance. The potential to improve surgical training, resource allocation and the quality of care was deemed to justify the use of retrospective data.

# Statistics

The statistical plans were designed and analyses performed by the authors of the presented papers. All statistical analyses were conducted using IBM SPSS® Statistics ver. 25 (IBM Corp., Armonk, NY, USA). P-value of <0.05 was considered statistically significant. Descriptive statistics were applied in all four studies.

Comparisons between groups were performed using the Mann-Whitney U-test. Proportions were presented as numbers and percentages, and comparisons were made using the chi-square test.

Binary logistic regression analyses were performed to evaluate associations between multiple factors and binary outcomes, with adjustments made for variables considered clinically important.

In Paper I, binary logistic regression analyses of patients undergoing emergent procedures were adjusted for ASA classification, tumor stage, indication for emergency surgery and procedures performed outside regular working hours.

In Paper II, Cox regression analyses were adjusted for patients´ age, gender, ASA classification, tumor stage, overall surgical experience, indication for emergency surgery, nighttime surgery, and adjuvant chemotherapy.

In Paper III, binary logistic regression for elective procedures were adjusted for patient sex, ASA classification, tumor stage, surgeon annual resection volume and surgical approach. For emergent procedures, binary logistic regression was adjusted for ASA classification, surgeon´s annual resection volume, overall surgical experience, tumor stage, nighttime surgery, and indication for emergency surgery. Cox regression analysis for elective resections was adjusted for patients´ sex, patient age, ASA classification, tumor stage, annual surgeon resection volume, overall surgical experience, and surgical approach. For emergent resection, the same variables were included, with additional adjustment for nighttime surgery and indication for emergent surgery.

In Paper IV, the binary logistic regression analyses were adjusted for the hospital at which the operation was performed, patient age and sex, ASA classification, tumor stage, indication for emergent surgery, night-time surgery, surgical experience, surgeon annual resection volume, and whether the surgeon had colorectal subspecialization. Adjustments for confounders in the Cox regression model were the same, with the addition of adjuvant treatment when assessing CFS.

Kaplan Meier's survival analysis was used to compare OS and CFS survival between the groups in Paper II, Paper III and Paper IV. OS was calculated from the date of surgery to the last date of follow-up, counting deaths as events and the

remainder as censored. Furthermore, CFS was calculated from the date of the surgery to the date of recognized cancer recurrence or death. The remaining patients were censored. A log-rank test was utilized to test differences in OS and CFS between the groups.

In Paper II, Paper III and Paper IV, Cox hazard regression analyses were performed to evaluate the effect of multiple variables and to adjust for potential confounders in analysis of OS and CFS.

# Outcomes of interest

Paper I: Effects of surgical specialization and surgeon resection volume on postoperative complications and mortality after emergency CC resection.

Paper II: Impact of surgical specialization on long-term survival after emergency CC resection.

Paper III: Short- and long-term postoperative outcomes after CC resections performed by male and female surgeons: A single center retrospective cohort study.

Paper IV: Short- and long-term postoperative outcomes after emergency CC resection, performed by male and female surgeons: A multicenter retrospective cohort study.

# Results

## Paper I and Paper II

Between January 1, 2010, and December 31, 2020, a total of 1,121 patients underwent CC resection at Helsingborg Hospital. Of these, 886 patients (79.0%) underwent elective and 235 patients (21.0%) underwent emergency procedures, a distribution consistent with previously reported proportions of elective versus emergency CC surgery (91, 158) (Figure 6). All procedures were performed by board-certified surgeons. Patients requiring emergency resections were managed pre-, peri- and postoperatively exclusively at Helsingborg hospital. Following data validation, no missing data were observed. No patients were treated with SEMS as bridge to elective surgery. The distribution of surgeons and procedures are presented in Figure 5.

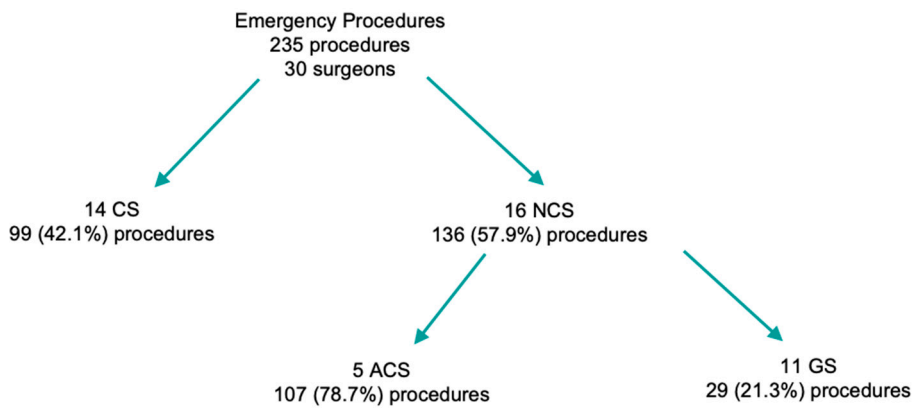


**Figure 6.** Flow chart of the emergent colon cancer procedures presented in Paper I and Paper II according to the performing surgeons´ subspecialization.

Patients' characteristics and operative variables did not differ significantly between emergency resections performed by CS and NCS. The only exception was among patients with left sided tumors, where the proportion of protective stomas was

significantly higher in procedures performed by CS. There was no difference in $R_1$ resections between patients operated on by CS and NCS.

In a subgroup analysis, comparing patients operated on by CS, ACS and GS, patients characteristics and operative details were comparable across groups. However, a single exception was observed in perioperative blood loss, which was greater among patients operated by GS compared with those operated on by CS and ACS (p=0.008).

## Surgeon subspecialization

AL, intra-abdominal abscesses, SSI, and reoperations were similar between patients undergoing emergency CC resection performed by CS and NCS. Unplanned readmissions were more frequent after surgery performed by NCS, with adjusted 4.2 odds compared with that of CS.

The subgroup analysis of readmission demonstrated that patients operated on by ACS had 3.5 times and by GS had 7.0 times higher odds of readmission after surgery than patients operated by CS (Table 7). Resections performed by GS were associated with 2.5 increased OR of any complication and reoperation compared with ACS, which was an association not observed for procedures performed by CS.

**Table 7.** Postoperative complications and clinical outcomes after emergency colon cancer resection according to the performing surgeons´ subspecialization in Paper I

| | Resections performed by | | | |
|---|---|---|---|---|
| | **CS** n=99 | **ACS** n= 107 | **GS** n= 29 | **p-value** |
| **Any complication** | 54 (54.5%) | 49 (45.8%) | 20 (69%) | 0.011 |
| - Binary regression, OR (CI 95%) | 1.4 (0.8-2.4) | Reference | 2.5 (1.1-6.1) [a] | |
| **Reoperation** | 12 (12.8 %) | 6 (5.6 %) | 6 (20.7) | 0.042 |
| - Binary regression, OR (CI 95%) | 2.3 (0.7-6.8) | Reference | 4.2 (1.1-16.0) [a] | |
| **Readmissions** [b] | 4/95 (4.2 %) | 12/100(12.0 %) | 6/26 (23.1) | 0.011 |
| - Binary regression, OR (CI 95%) | Reference | 3.5 (1.1-11.6) | 7.0 (1.7-29.2) [a] | |

**Note** [a] Binary regression analysis with adjustments for ASA classification, tumor stage, indication for emergent surgery, and surgery performed outside regular working hours.
[b] Patients with in-hospital mortality rate excluded from analysis.
CS, Colorectal Surgeon. ACS, Acute Care Surgeon. GS, General Surgeon. n=number of patients. Outcomes are expressed as OR, Odds Ratio and CI, Confidence Interval 95%.

## Surgeon resection volume

The median annual surgeon case volume for all CC resections was 8.9 (range 1.2-8.4) procedures annually. For emergency resections performed by the most senior surgeon, the median annual resection volume was 4.1 (range 1.2-8.4) per year. CS

had a substantially higher annual resection volume compared with NCS (median 18.7, IQR 9.8-27.5 vs 2.4, IQR 0.9-6.0).

Surgeons were stratified into high-, intermediate-, and low-volume groups based on annual case volume:

- High volume >8.4 procedures per year (n=7)
- Intermediate volume: 4.1-8.4 procedures per year (n=9)
- Low volume: <4.1 procedures per year (n=14)

Patients' characteristics and operative details were comparable across surgeon volume groups. All high-volume surgeons were CS. Postoperative complications were lowest among patients operated on by surgeons with intermediate annual volume. In contrast, the complication rate was significantly highest in patients operated on by surgeons with the highest resection volume, which differed from that of surgeons with intermediate resection volumes (OR 4.2 (1.1-16.0)).

# Results Paper II

The median follow-up was 3.6 years (range 0.0-5.0). Median follow-up among diseased patients was 1.5 years (range 0.0-4.99), while survivor's completing the study period had a median follow-up of 5.0 years (range 2.4-5.0).

OS and CFS did not differ significantly between patients operated on by CS and NCS, findings confirmed by Cox regression analyses.

Survival outcomes were comparable between patients operated on by CS and ACS. In contrast, patients operated on by GS had significantly shorter OS and CFS. In Cox regression analysis, surgery performed by GS was associated with nearly twofold increase in hazard ratio for both OS (HR 1.78 (CI: 1.05-3.00), p=0.031) and CFS (HR 1.83 (CI: 1.02-3.26), p=0.041).

# Results Paper III

CC resections were performed by twenty-three male and nine female surgeons with no significant difference in annual resection volumes between the surgeon groups (p=0.122). A similar pattern was seen for elective procedures where 10 male and 9 female surgeons operated, again with no significant difference in annual resection volumes (p=0.762). Emergent CC procedures in Paper I and Paper II were performed by a total of thirty surgeons. During the preparation on Paper III, additional procedural data not documented in the medical records was identified from the surgery planning system, leading to the recognition of one additional senior surgeon. Consequently, emergent resections in paper III were performed by thirty-one surgeons, comprising twenty-three male and eight female surgeons.

Patients´ and procedure characteristics were comparable between patient operated on by male and female surgeons. Postoperative short- or long-term outcomes after elective resections did not differ by surgeon gender. In contrast, after emergency procedures, patients operated on by female surgeons had significantly higher rates of $R_0$ resection and fewer complications, fewer severe complications, reoperation and ICU admissions (Table 8).

**Table 8.** Postoperative complications and clinical outcomes after emergent colon cancer resections in patients operated on by female and male surgeons in Paper III.

| | Resections performed by | | |
|---|---|---|---|
| | **Female surgeons** n=80 | **Male surgeons** n= 155 | **p-value** |
| **Any complication** | 33 (41.3%) | 92 (58.7%) | 0.011 |
| - Binary regression, OR (CI 95%) | Reference | 2.4 (1.3-4.6) [a] | 0.006 |
| **ICU-care** | 5 (6.3%) | 27 (17.4%) | 0.018 |
| - Binary regression, OR (CI 95%) | Reference | 3.1 (1.1-8.8) [a] | 0.035 |
| **Reoperation** | 3 (3.8 %) | 22 (14.2 %) | 0.014 |
| - Binary regression, OR (CI 95%) | Reference | 4.9 (1.3-18.2) [a] | 0.017 |

**Note** [a] Binary logistic regression analysis with adjustments for ASA classification, the annual surgeon resection volume, overall surgical experience, tumor stage, night-time surgery, and indication for emergent surgery. Outcomes are expressed as OR, Odds Ratio and CI, Confidence Interval 95%. n=number of patients. ICU, Intensive Care Unit.

After elective procedures there were no differences observed in OS and CFS between patients operated on by male or female surgeons. In contrast, following emergency surgery, patients operated on by male surgeons had significantly shorter OS (HR 1.9 (CI: 1.3-2.8), p=0.001) and CFS (HR 1.7 (CI: 1.1-2.7), p=0.016) compared with patients operated on by female surgeons, an association that persisted after adjusted Cox regression analysis.

# Results Paper IV

Between January 1, 2010, and December 31, 2020, a total of 7 152 patients underwent elective CC resection at the ten participating hospitals. Emergent procedures for CC were performed in 1 452 patients, of which 1 307 patients underwent surgical resection and 145 underwent surgery but without resection of tumor (Figure 7).

Female surgeons were earlier in their post-certification careers, but emergency resection volumes and colorectal subspeciality training were comparable between the groups of surgeons.

Patients' and procedural baseline characteristics were comparable between CC resections performed by male and female surgeons, including BMI, ASA classification, timing of surgery, tumor stage, type of resection, stoma formation, lymph node yield and tumor TNM stage.

Importantly, proportion of resected tumors and time to surgery did not differ between the groups.

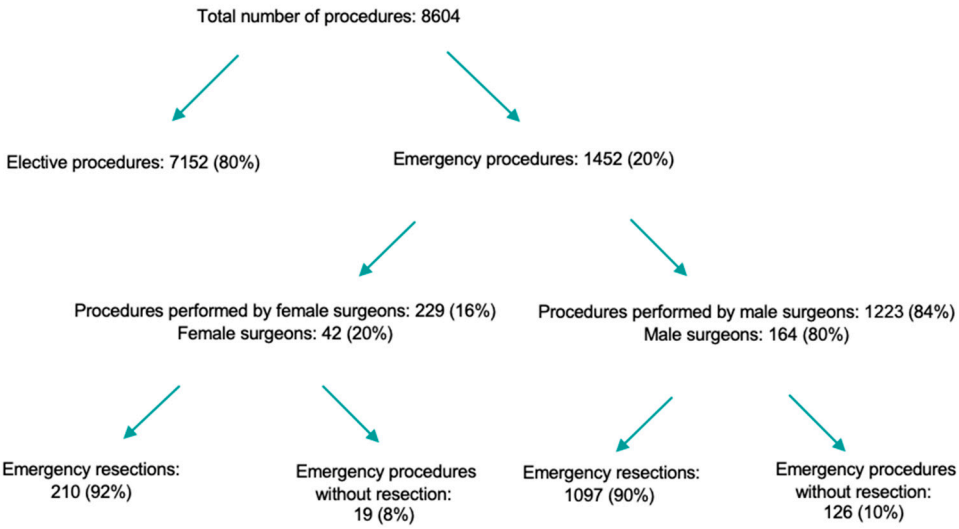


**Figure 7.** Flow chart of the elective and emergent colon cancer procedures presented in Paper IV according to the performing surgeons´ gender.

Postoperative outcomes favored patients operated on by female surgeons, with fewer postoperative overall complications and severe complications, fewer patients in need of ICU-care and fewer reoperations, findings that remained significant after the multivariable adjustment (Table 9).

**Table 9.** Postoperative complications and clinical outcomes after emergent colon cancer resections performed by surgeon gender in Paper IV

| | Resections performed by | | |
|---|---|---|---|
| | **Female surgeons** n= 210 | **Male surgeons** n= 1097 | **p-value** |
| **Any complication** | 98 (46.7%) | 631 (57.5%) | 0.004 |
| - Binary regression, OR (CI 95%) | Reference | 1.72 (1.24-2.41) [a] | 0.001 |
| **Clavien-Dindo > III** | 19 (9.9%) | 163 (14.9%) | 0.026 |
| - Binary regression, OR (CI 95%) | Reference | 2.05 (1.78-3.59) [a] | 0.012 |
| **ICU-care** | 26 (12.4%) | 165 (15.0%) | 0.317 |
| - Binary regression, OR (CI 95%) | Reference | 1.35 (0.82-2.22) [a] | 0.233 |
| **Reoperation** | 14 (6.7 %) | 120 (10.9 %) | 0.062 |
| - Binary regression, OR (CI 95%) | Reference | 2.07 (1.12-3.84) [a] | 0.021 |

**Note** [a] Binary logistic regression analysis with adjustments for patient age and gender, ASA-classification, night-time surgery, indication for emergent surgery, surgical experience, colorectal surgeon, annual surgeon resection volumes, tumor stage, and hospital. Outcomes are expressed as OR, Odds Ratio and CI, Confidence Interval 95%.

After adjustment for clinically relevant factors, OS and CFS were longer among patient operated on by female surgeons, whereas emergent resections performed by male surgeons were associated with shorter OS (HR 1.42 (1.14-1.78), p=0.002) and CFS (HR 1.14 (1.07-1.82), p=0.013).

In Paper IV, missing data was observed for BMI 73 patients (5.6%), intraoperative bleeding for 35 patients (2.7%) and the lymph node yield for 9 patients (0.7%), but these variables were not considered confounding factors, not included in the binary logistic or Cox regression analysis.

# Discussion

The main aim of this thesis was to investigate the relationship between surgeon-related factors and the patients´ postoperative short- and long-term outcomes after CC resection. A fundamental ethical principle of medical practice, *do no harm*, implies that it is important to understand and mitigate the impact of the individual surgeons' variations in decision-making and operative performance. Well-established determinants for outcome include patient-, tumor- and system-related factors, but the influence of surgeon-related factors remains relatively unexplored. The potential impact of surgeon specialization, annual operative volume, and the gender of the surgeons, on patients' postoperative outcomes, have not yet been fully revealed. This knowledge gap is especially evident in emergency CC surgery, where patients are often physiologically unstable, procedures are technically demanding, and the risk of postoperative morbidity and mortality is substantial. In such high-risk circumstances, the impact of surgeon decision-making, operative technique and perioperative management may be amplified into measurable differences in patient outcome.

The main observations in Paper I and Paper II were that there was no difference in postoperative complications, 30- and 90-day mortality, and oncological quality between patients operated on by CS and ACS. In contrast, patients operated on by GS experienced less favorable outcomes, characterized by higher rates of postoperative complications, reoperations, and readmissions as well as shorter long-term survival. Surprisingly, no difference in oncological quality was identified when comparing patients operated on by CS and ACS. In Paper III and Paper IV, the influence of surgeon gender on postoperative short- and long-term outcomes after CC resection, was examined in a single-center and a multi-center setting and no gender-related differences were observed after elective procedures. In contrast, following emergency resections, patients operated on by female surgeons experienced fewer overall and severe postoperative complications, fewer reoperations and $R_1$ resections. Patients operated on by male surgeons had shorter OS and shorter CFS.

To assess the external validity, a multi-center study including patients undergoing emergent CC resections at ten hospitals in southern Sweden was performed. Consistent with the findings in Paper III, female surgeons demonstrated fewer postoperative complications and reoperations, as well as improved OS and CFS compared with their male counterparts after emergency CC resection. Collectively, these finding suggest that the surgeon's subspecialization and gender may influence patient outcomes after emergency CC resections.

## Surgeon specialization

Sweden is a geographically large country with a relatively small population of patients with CRC, handled at hospitals with varying annual volumes of CC surgery. Procedures for emergency CC are frequently performed at Regional hospitals during on-call hours. The question of centralization of care is of both clinical and organizational importance. Evidence from elective colorectal surgery shows benefit of surgical specialization and the annual volume of the surgeon for patients postoperative outcomes, but the relevance of these factors in the emergency setting is less clear (100).

Paper I and Paper II contribute to this debate by showing that CS and ACS deliver comparable outcomes for patients following emergency CC resection. In contrast, patients undergoing emergency CC resection by GS experienced higher postoperative morbidity and shorter long-term survival, even though no differences were identified in the oncological surgical quality. The GS are categorized by being vascular, breast or upper GI surgeons, who are supposedly less exposed to decision making in general emergency surgery and elective CC surgery.

Some studies support the benefit of patients with emergency CC being operated on by CS, resulting in lower morbidity and mortality, compared to patients being operated on by GS (12, 100). In contrast, a study published in 2025 by Orbach et al., reported comparable short- and long-term outcomes between CS and GS for patients undergoing urgent colectomies with an end stoma, suggesting that well supported NCS emergency services can achieve similar results (159).

These findings frame a central Swedish healthcare policy dilemma, centralization versus access to surgery. Further centralization of colorectal cancer surgery may improve outcome for elective oncological patients, but it also carries the risk of eroding emergency surgical competence in rural and primary care hospitals where patients with emergency surgical presentations must still be treated promptly. Furthermore, as laparoscopic techniques continue to expand, perhaps including increased laparoscopic approach in emergency colorectal surgery, disparities in surgical expertise, resources, and training may become more pronounced, potentially amplifying outcome differences between centers and surgeons in the future.

From an equality perspective, the goal should not be to make emergency CC surgery dependent on the presence of CS at all hours but rather to ensure a continued education on specialist level for NCS, sustained competence in the emergency surgery teams, and an organization with a robust system to prevent and highlight complications.

# Postoperative complications

In Paper I and Paper IV, the postoperative complications rates were consistent with those reported in previous studies (12, 108, 160). Although, SCRCR is a validated registry, the findings identified a considerable degree of misclassification of postoperative complications. In the single center cohort (Paper I, Paper II and Paper III), the postoperative complications differed by 15% when comparing the SCRCR data with the data from the patients' medical records. This finding is consistent with a validation of the SCRCR, performed by Arnarson et al., which showed registration of postoperative complications were unreliable, but reliable for severe complications (72). Consequently, comparisons of complication rates between studies bases on different registers, with or without additional journal review, should be interpreted with caution.

The rate of postoperative complications were 2.5 times higher for patients operated on by GS, compared to CS and ACS. One possible explanation may be that GSs primary surgical practice does not involve neither colorectal nor acute care surgery, resulting in less procedural exposure to emergency CC surgery.

The single-center study in Paper III and the multi-center study in Paper IV demonstrated favorable postoperative outcomes for patients operated on by female surgeons. In Paper III and Paper IV, the odds of postoperative complication were 2.4 times respectively 1.72 times higher when surgery was performed by a male surgeon. In the multicenter cohort, the odds of severe complications, Clavien-Dindo>II, were twice as high among patients treated by male surgeons. These associations remained after adjustment for surgical specialization, annual resection volume and surgical experience. The patients´ baseline characteristics, severity of disease, and timing of surgery were not found to be different between the groups, making selection bias unlikely. Although no patients who were not operated on or reassigned to another setting/surgeon were identified, a potential source of selection bias, no such bias was evident in the available data. Nevertheless, the reasons underlying these differences remain unclear, suggesting that surgeon-related factors may play an independent role in postoperative outcomes.

Gender-related differences in surgeons´ personal traits and behavioral patterns have been explored in prior research, with female surgeons reported to score higher on measures of conscientiousness, agreeableness and extraversion (144). It has been suggested that female physicians may adopt a more guideline adherent and risk-averse approach in clinical decision making which are findings that are primarily derived from research within internal medicine and non-surgical settings (97, 145). Such traits may be particularly relevant in high-stakes environments such as emergency surgery, where surgeons must make rapid, experience-based decisions under conditions of uncertainty and time pressure. These circumstances are comparable to studies in aviation and military contexts, where recognition-primed decision-making is preferred in time-pressured situations, while analytic strategies are more appropriate in elective, stable settings (161).

Previous studies that assessed the potential association between surgeon gender and postoperative outcomes have made conflicting conclusions. Some studies, like Wallis et al, report improved postoperative outcome for patients operated by female surgeons (97, 122-126, 162), while other report no difference (127, 128, 130-132). However, many of these studies were limited by gender imbalance among surgeons with less than 5.5% female surgeons compared with 94.5% male (131), inclusion of mixed surgical specialties, and a combination of elective and emergency procedures (97), making interpretation challenging. This thesis is the first to evaluate surgeon gender differences in a more homogeneous cohort of emergency CC patients.

In emergency CC surgery, decisions regarding resection, damage control, anastomosis versus stoma must often be made on incomplete information. Understanding how stress and decision-making interact with gender may therefore provide insight into surgeons pre- and perioperative judgment. However, when examining surgical outcomes, the results are inconsistent. These findings may indicate that any observed differences can be multifactorial, influenced by institutional and cultural factors, possibly to a great extent, together with biological traits.

## Oncological quality

The oncological quality indicators potentially affected by surgical technique in this thesis, including lymph node yield and $R_0$ resection status, were similar across surgical specializations and surgeon annual volume groups in Paper I and Paper II, although their distribution differed between groups. These findings imply that oncologic surgical principals were upheld regardless of surgeon surgical specialization and surgeon annual volume. Given that the lymph node yield and $R_0$ resection rate are strong predictors of long-term survival, the absence of differences strengthens the interpretation that inferior outcomes of patients operated on by GS are more likely attributable to factors other than intraoperative technical or oncologic inadequacy.

In Paper III and Paper IV, female surgeons demonstrated significantly lower $R_1$ rate compared to the male surgeons. The reasons for this remain unclear, however, studies have demonstrated superior manual dexterity among female surgeons, and female students have been shown to score significantly higher in hands-on suturing practice performance compared to their male counterparts. It is plausible that similar differences may also apply to the female surgeons in the present study (122, 138, 140).

## Postoperative mortality

Across Paper I, Paper III and Paper IV, no statistically significant differences in 30-day and 90-day mortality were observed between patients operated on by the different surgeon groups. The overall mortality rates are consistent with previously reported data in the literature, suggesting that the outcomes in this cohort are representative. This interpretation is further supported by Swedish national data

indicating that 8.8% of patients died within 90 days following emergency resection during 2022-2024 (20). Notably, there was no identified difference in the postoperative mortality rate across the categories of surgeons studied.

In contrast, Biondo et al. reported a lower 30-day mortality rate for patients operated on emergently by CS compared to GS, (6.7% vs. 16.4%, p=0.001), a finding supported by Kulaylat et al. that demonstrated a difference in outcome after emergency CC surgery between patients operated on by CS and GS (17.8% vs 28.3%, p<0.001)(12, 160). In a study on 14 000 patients undergoing emergency CRC resections (163). Patients operated on by non-CS were significantly more likely to die within 30-days and 90-days, and less likely to survive until two years compared with patients operated on by CS.

The differences in 30-day and 90-day mortality in this thesis may be explained by standardized national guidelines and a high surgical training across Swedish hospitals. In addition, established care pathways and inter-hospital collaboration may reduce differences related to surgeon specialization or hospital level. The mortality rates in this thesis were comparable to those reported for CS at tertiary centers. In Sweden, approximately 80% of emergency CC resections are performed at regional hospitals and the findings in this study support that emergency CC resections can safely be performed further in these centers.

## Surgeon gender

Surgeon-related factors influence postoperative and long-term outcomes through mechanisms that span throughout the pre-, peri-, and postoperative phases of care. The mechanisms behind gender-associated outcome differences are complex and difficult to isolate.

In Paper III and Paper IV, there was no difference in patient baseline characteristics including ASA classification, age, tumor stage, comorbidity, the indication for emergency procedure and the event of night-time surgery between surgeon genders. This suggests that the patient selection does not account for the observed outcome differences.

Surgeon-gender-related differences likely arise from a combination of individual surgical characteristics, technical skills, communication, and personal traits, but also on broader workplace culture and organizational factors including teamwork and clinical norms. These elements interact in a multifactorial manner, making it challenging to attribute the differences in outcome between male and female surgeons' gender to any single factor.

Previous studies have suggested that female surgeons adopt a more patient-centered communication style that may potentially result in explaining operative risk and treatment options better, resulting in improving patients understanding of their disease and adherence to protocol (164). A more patient-centered communication

style may improve patients' understanding of their disease, promoting adherence to perioperative protocols and facilitating earlier recognition of complications, potentially leading to better outcome.

In the perioperative phase, results in Paper IV showed that patients undergoing surgical procedures by female surgeons had significantly less perioperative blood loss and fewer $R_1$ resections. Gender-associated differences in adherence to safety checklists, compliance to guidelines, and operative decision-making have been proposed to have an impact that can lead to a reduction in adverse intraoperative events. Blohm et al., found longer operating time for patients operated by female surgeons, but less postoperative complications after elective cholecystectomies, suggesting that the longer operating time reflect caution in surgical access and dissection by the female surgeons (123). In contrast, one study showed that female surgical residents demonstrated superior academic achievement compared with their male colleagues, but scored less well on visuomotor task, a task that according to the authors is a predictor for operative skill (139). However, a systematic review demonstrated inferior results regarding technical skills for female medical students compared with male students, but in the same study, no differences were seen between male and female surgical residents (141). These findings suggest that this performance difference may diminish with training, as no difference was observed between male and female residents. Surgical training functions as a selective process in which individuals who become surgeons regardless of gender will acquire the necessary skills and decision-making ability over time.

In the postoperative phase, patients operated by female surgeons experienced fewer overall complications and fewer severe complications. The previously discussed differences between male and female surgeons in adherence to checklists, compliance to guidelines, and decision-making may contribute to identify complications early in the postoperative phase and manage deviations, which can prevent minor complications from progressing to adverse events. This is consistent with the observations in Paper III and IV, that the rate of reoperations was nearly twice as high among patients treated by male surgeons.

Many of the existing studies on surgeon gender suffers from methodological limitations. Several studies combine multiple surgical specialties, procedures of widely varying complexity and patients undergoing elective and emergency procedures(97, 128, 130). This heterogeneity makes it harder to detect true gender-related differences, especially in low-risk procedures, because these procedures have fewer complications and are therefore less likely to reveal such differences. Additionally, the surgeon gender distributions in the literature are often highly imbalanced, with female surgeons being less prevalent (125). This combination of heterogeneous cohorts and gender imbalance complicates interpretation and partly explains the inconsistence of findings in the literature. More homogeneous study populations and a higher proportion of female surgeons are needed to reliably assess the influence of gender on surgical outcomes. However, to my knowledge, none of the existing studies demonstrate superior outcomes for patients operated on by male surgeons.

This pattern may suggest that certain behaviors or practice styles are more commonly observed among female surgeons and may positively influence patient's outcome. Recognizing these differences is important, not to ascribe fixed traits to surgeon gender, but to identify practice patterns that could be trained to enhance surgical care. Awareness of how communication, operative behavior, and clinical culture shape outcomes may encourage reflection and improvement across the surgical profession. The overall aim of surgery is to improve survival and quality of life for our patients and insights in gender associated differences may therefore help to form strategies that optimize patient care for all.

## Long-term outcomes

Most recurrences following surgery for CRC occur within the first three years after operations with curative intent (165). Structured CT surveillance is the cornerstone of postoperative follow-up but have a moderate diagnostic accuracy for recurrence detection overall. The sensitivity for metastatic recurrence for CT is 50-60%, and the specificity 65-70%, reaching clinically acceptable detection rates if combined with clinical assessment and monitoring of CEA (166).

The long-term survival outcomes observed in this thesis, are consistent with data from SCRCR and international reports on patients undergoing emergency CC resections (3). In Sweden, registry-based studies have demonstrated shorter survival for patients undergoing colon resection with emergency presentation compared with elective resections. Five-year OS after emergency CC resection is reported to range from 35% to 45%, and the five-year survival after elective surgery range from 50% to 60% (86, 167). Comparable patterns have been reported internationally, with large cohorts consistently demonstrating 5-year survival of 35% to 45% after emergency CC surgery and 55% to 70% following elective resections, accompanied by corresponding differences in CFS (12, 86).

Importantly, stage-stratified analyses demonstrates that the disadvantages in survival associated with emergency presentation persists even within the same TNM stage, particularly in stage II and III disease. This supports the hypothesis that emergency presentation of CC reflects a more advanced tumor biology and an increased treatment-related risk (12).

In Paper II, both OS and CFS were significantly shorter for patients operated on by GS compared to patients operated on by CS and ACS. The two-fold increased risk of death and recurrence for patients operated on by GS, suggest that surgical specialization independently influences patients' long-term survival after CC resection.

OS and CFS were shorter for patients operated on by male surgeons as demonstrated in Paper III and Paper IV. An underlying mechanism could potentially be explained by differences in the burden of postoperative complications. In previous studies, postoperative complications have been shown to adversely affect the long-term survival after colorectal surgery (168, 169). In the present thesis, patients

operated on by GS (69% in Paper I) and those operated on by male surgeons (58.9% in Paper III and 57.5% in Paper IV), exhibited higher proportion of postoperative complications. These complications may contribute to inferior long-term survival, through several pathways, including delayed recovery and postponement of adjuvant chemotherapy.

In addition, oncological quality of resection represents a potential explanatory factor. $R_1$ resection margins is associated with reduced OS and CFS after CC surgery (63, 65, 66). Notably, in Papers III and Paper IV, patients operated on by male surgeons had a higher frequency of $R_1$ resections, which may further contribute to the observed survival disadvantage.

Furthermore, emerging evidence suggests that the treatment strategy at emergency presentation may have substantial impact on long-term outcomes. In a Swedish study by Arnarsson et al., SEMS or diverting stoma as a bridge to elective surgery in patients presenting with emergency CC were assessed. Bridge to surgery was shown to improve the 5-year OS from 37.4% in patients undergoing emergency resection, to 53.8 % (167). This highlights the potential benefit of avoiding definitive emergency resection when feasible. SEMS as a bridge to surgery were not used in the population in Paper I through Paper III. In Paper IV, 122 patients received SEMS, but none were managed as a bridge to surgery. Furthermore, among patients presenting with emergency symptoms who underwent surgery, no differences were observed between those operated on by male or female surgeons, with regard to stoma formation without resection.

# Limitations

This thesis includes four retrospective, observational studies. Statistical adjustments were made to the best of our ability for known confounding factors, such as surgeon's annual resection volume and night-time surgery. However, other factors such as team dynamics or postoperative pathways, that may have influenced the observed associations were beyond the reach of the present thesis´s methodology. Retrospective studies rely on the accuracy of existing documentation, which introduces a risk of measurement bias and inconsistent reporting resulting in incomplete data. The retrospective approach was chosen because it allows the study of rare and high-risk procedures across large populations, a design neither possible, ethical or practically feasible in a randomized controlled trial (RCT). A RCT would have been able to provide stronger evidence, but it is not possible to randomize emergency CC resection surgery, according to a specific surgical specialization or surgeon gender, making the retrospective registry design the most realistic research methodology to assess the effect of surgical specialization or surgeon gender.

A difference between Paper I to III and Paper IV was the definition of emergency procedures. In the single cohort study, emergency procedures were defined as those

performed within 48 hours of admission, whereas in the multicenter study we applied SCRCR criteria, defining emergency procedures as operations performed acutely due to the medical indication, regardless of timing. This discrepancy may limit direct comparability between the studies. However, we performed a subgroup analysis in Paper IV and found no evidence that the definition of emergency surgery affected the results.

The results across all four papers are limited by the registration and classification of postoperative complications. Despite high coverage and strong completeness of the SCRCR, postoperative complications are known to be underreported. The manual validation therefore strengthens the data accuracy in these studies and confirmed earlier evidence of the limited reliability of postoperative complications in the SCRCR (72). Furthermore, no formal inter-rater reliability test was performed across the study populations, which could have further strengthened the assessment of consistency and robustness of complication registration.

One limitation to address is the method used to categorize the participating surgeons according to annual resection volume. The median annual elective and emergency resection volume for the surgeons was calculated. The surgeons were divided into groups of low, medium and high-volume surgeons. Surgeon volume was defined using annual resection volumes among participating surgeons instead of predefined volume cut-offs. This approach will reduce comparability with other studies, it reflects the absence of internationally accepted thresholds for defining surgeon volume. Notably, surgeons with the highest resection volumes were solely CS, making it unlikely that the observed differences are explained by conflicting volume-based categorization rather than true differences in specialization. This interpretation is further supported by the subspeciality analyses showing more favorable outcomes for CS and ACS compared with GS, who were largely represented in the low-volume group of surgeons. Furthermore, the number of resections performed by GS in Paper I and II, was limited, and the findings should therefore be interpretated with caution.

In Paper III and Paper IV, surgeon gender was classified using surgeons first name or by personal communication, however this approach identifies biological sex, and it does not capture self-identified gender and may not fully account for sociocultural factors that influence behavior or practice patterns.

Although surgical timing was recorded, surgeon-specific influences on operative timing could not be fully evaluated. While unstable patients required immediate surgery, differences in timing decisions among clinically stable patients cannot be excluded, and it therefore remains unclear whether such differences varied by surgeon gender.

Paper IV improves external validity but introduces heterogeneity between hospitals. Hospital inclusion was based on centers willingness to participate through established professional networks. One of centers in the region declined to participate for ethical reasons. Ten hospitals of varying size and case volume were included as this was considered sufficient to capture variations in clinical practice. Differences

in resources, staff structures, and pre-, peri-, and postoperative routines may contribute to residual confounding factors not considered in the adjustment of the data.

The ten participating hospitals were selected via the authors´ informal network. An alternative methodological approach would have been to include a complete cohort of consecutive patients from the SCRCR. This would include all Swedish units that perform colon resections with a larger representation of operating surgeons. The downside of this would be a reduced data accuracy and greater potential for misclassification.

## Bias

Bias is an unavoidable consideration. In Papers I to Paper III, the risk of selection bias is considered low as the study population consisted of a homogenous group of patients undergoing the same complex procedure at the same hospital. All eligible patients during the study period were included, and no systematic differences in baseline characteristics were identified between surgeon groups, which makes it less likely that patients with different comorbidities were preferentially operated by certain surgeons.

However, performance bias related to hospital-specific factors in Paper IV cannot be fully excluded. Outcomes could be influenced by local team structure, available staff, and workplace culture, which are inherently constant within Paper I through Paper III as the papers are based on a single center population.

The risk of measurement bias was minimized by using data from the SCRCR with a coverage of 98.5% of patients with CRC. Missing data was minimal and not systematically associated with short- and long-term outcome.

Statistical analyses were conducted by the research team, which may introduce analytical bias, however, standardized and transparent statistical methods were applied to mitigate this risk.

Confounding represents an important source of bias. Although multivariate adjustments were performed for patient-, tumor-, and procedure related factors, residual confounding due to unmeasured or incompletely measured variables, such as surgeons experience beyond volume and surgical specialization, intraoperative decision-making, or differences in postoperative care may persist. A Directed Acyclic Graph (DAG) analysis was not performed but could have strengthened the identification and justification of the confounders included in the adjustment.

In Paper IV, selection bias is a limitation. The recruitment of participating hospitals was based on established professional networks and willingness to participate, resulting in a non-systematic multicenter cohort. This method may have led to systematic differences between participating and non-participating hospitals, including variation in case mix, institutional culture, and resource availability. Consequently, patient selection at hospital level may limit the representativeness of the cohort.

Finally, information bias should be acknowledged. Study protocols were not published prior to data analysis, which limits external scrutiny of predefined hypotheses and analytical plans. Prospective protocol registration in future studies would enhance transparency and allow peer input at an early stage and reduce the risk of selective outcome reporting.

Despite these limitations, the convergence of findings across the four papers, the use of a homogeneous surgical cohort, and the validation of registry data strengthen the internal validity of this thesis. Furthermore, the inclusion of several hospitals in Paper IV improves generalizability and provides a robust foundation for concluding that surgeon-related characteristics, surgical specialization, operative volume and surgeon gender are associated with variations in postoperative outcomes following CC resection.

# Conclusions

- Postoperative morbidity and mortality after emergency CC resection did not differ between patients operated on by CS and ACS. However, higher postoperative morbidity was observed among patients treated by GS.
- Postoperative mortality was comparable between patients across surgeon specializations and annual resection volume groups.
- Postoperative complications were significantly higher among patients operated on by surgeons with high annual resection volume.
- OS or CFS did not differ between patients operated on by CS and ACS, however, patients operated on by GS experienced shorter OS and CFS.
- Patients operated on by female surgeons experienced fewer and less severe postoperative complications and fewer reoperations after emergency CC resection.
- Patients operated on by female surgeons had longer OS and CFS after emergency CC resection.

# Sammanfattning på svenska

Kolorektalcancer är den tredje vanligaste cancerformen i Sverige, med ca 7 100 nya fall per år, varav cirka 5 000 utgörs av tjocktarmscancer och 2 100 av ändtarmscancer. Kirurgi är den enda botande behandlingen och cirka 70–80% av patienterna är aktuella för resektionskirurgi. Överlevnaden har successivt förbättrats och idag lever ungefär 65 % av patienterna 5 år efter diagnos.

Trots framsteg kvarstår det betydande utmaningar, framför allt på grund av den höga risken för postoperativa komplikationer efter koloncanceroperation. Komplikationsfrekvensen uppgår till cirka 30 % efter planerad kirurgi och till 50 % efter akut kirurgi, vilket medför ökat lidande för patienterna, förhöjd mortalitet, men också längre vårdtider och ökade samhällskostnader. Postoperativa komplikationerna efter koloncancerkirurgi inkluderar bland annat sårinfektion, lunginflammation, urinvägsinfektion, djup ven trombos, lungemboli, anastomosläckage, sepsis, hjärtinfarkt, stroke och död.

Under senare år har stort fokus lagts på att optimera patients förutsättningar inför operation. Parallellt har intresset ökat för hur kirurgrelaterade faktorer kan påverka patienternas postoperativa utfall. Det finns idag ett växande stöd för att även kirurgens individuella egenskaper och erfarenheter påverkar patientens postoperativa resultat.

Vid planerad tjocktarmscancerkirurgi finns stark evidens för att ingreppen bör utföras av kirurger med kolorektal inriktning, för att uppnå bästa möjliga resultat avseende patienters postoperativa utfall. Dessa resultat kan dock inte direkt överföras till den akuta patientgruppen. Patienter som är i akut behov av tjocktarmscancerresektion är ofta kritiskt sjuka med tillstånd som ileus (tarmvred) och perforation (hål i tarmen), vilket innebär både ett instabilt fysiologiskt tillstånd och en mer komplex kirurgisk situation där onkologisk radikalitet behöver balanseras mot akut livräddande åtgärder. Tidigare studier av akut koloncancerkirurgi har visat motstridiga resultat, och flera retrospektiva studier har rapporterat likvärdiga korttids resultat för patienter opererade av kirurger med kolorektal- och icke kolorektal inriktning.

Syftet med denna avhandling var att undersöka hur kirurgrelaterade faktorer såsom subspecialisering, årlig operationsvolym och kirurgens kön, påverkar patienters postoperativa morbiditet och mortaliteten samt total överlevnad och cancerfri överlevnad efter akut koloncancerkirurgi. Avhandlingen baseras på fyra studier med registerdata från Svenska Kolorektalcancerregistret (SCRCR) och inkluderar vuxna patienter som genomgått akut koloncancerresektion mellan 2010 och 2020. Registeruppgifter validerades genom journalgranskning med ett standardiserat protokoll.

Resultaten visar att kirurgens subspecialisering har betydelse för patienternas postoperativa utfall. Komplikationsfrekvensen var högre när operationen utfördes av allmänkirurger med annan inriktning än kolorektal- eller akutkirurgi, jämfört med operationer utförda av kolorektalkirurger eller akutkirurger. Någon skillnad i mortalitet mellan grupperna observerades dock inte. Långtidsutfallen visade sämre total överlevnad och cancerfri överlevnad hos patienter opererade av allmänkirurger med en annan inriktning än kolorektal- eller akutkirurgi.

Vidare identifierades tydliga skillnader relaterade till kirurgens kön vid akuta ingrepp. Patienter som opererades av kvinnliga kirurger akut hade färre postoperativa komplikationer, färre icke radikala resektioner, färre reoperationer och mindre behov av intensivvård. Trots likvärdig 30- och 90-dagarsmortalitet, var både total- och cancerfri-överlevnad sämre hos patienter som opererades av manliga kirurger jämfört med patienter opererade av kvinnliga kirurger. Dessa resultat bekräftades i en multicenterstudie.

Sammanfattningsvis visar denna avhandling att kirurgrelaterade faktorer har en betydande inverkan på utfallet efter akut koloncancerkirurgi. De observerade skillnaderna för patienterna, särskilt avseende kirurgens kön, understryker behovet av vidare forskning för att identifiera bakomliggande mekanismer. En ökad förståelse för kirurgrelaterade skillnader kan ses som en del av det kontinuerliga lärandet som präglar kirurgin som profession och som ytterst syftar till att förbättra patienternas utfall.

# Future perspectives

Previous research indicates that patient outcomes achieved by female surgeons are comparable to, and in some cases more favorable than, those achieved by male surgeons. However, the mechanisms underlying these differences remain incompletely understood. Previously proposed explanations have included variations in personality traits, communication styles, approach to risk assessment, and patient-centered decision-making, all of which may influence surgeons' clinical and operative decision-making.

A Swedish study published in 2024, examining gender-related differences in personality traits among surgeons, identified variations in conscientiousness, agreeableness, neuroticism and extraversion while no differences were observed in openness. Building on these findings, a future research direction could be to assess personality traits among the surgeons included in Paper IV using standardized and validated questionnaire regarding the BIG five personality traits. Linking these data to patient outcome measures would allow evaluation of association between specific surgeon personality characteristics and short- and long-term postoperative outcome.

Such an approach may help to identify personality traits associated with particularly favorable outcomes and contribute to a more nuanced understanding of factors characterizing high-performance surgeons. Rather than defining an idealized "super surgeon", this perspective emphasizes the potential importance of non-technical skills and individual behavioral characteristics in optimizing surgical decision-making and patient care. Insight gained from this work could potentially guide surgical training and professional development.

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# Paper I

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**Original Article**

# Effects of surgical specialization and surgeon resection volume on postoperative complications and mortality rate after emergent colon cancer resection

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## Abstract

**Background:** The aim of this study was to evaluate the effect of surgical specialization and surgeon resection volume on short-term outcome after emergent colon cancer resections.

**Methods:** A retrospective analysis of all patients who underwent resections for colon cancer between 2011 and 2020 at Helsingborg Hospital, Sweden was performed. The senior surgeon participating in each procedure was classified as a colorectal surgeon or a non-colorectal surgeon. Non-colorectal surgeons were further divided into acute care surgeons or surgeons with other specialties. Surgeons were also divided into three groups based on median yearly resection volumes. Postoperative complications and 30- or 90-day mortality rate after emergent colon cancer resections were compared in patients operated on by surgeons with different specializations and yearly resection volumes.

**Results:** Of 1121 patients resected for colon cancer, 235 (21.0 per cent) had emergent procedures. The complication rate of emergent resections was similar in patients operated on by colorectal surgeons and non-colorectal surgeons (54.1 *versus* 51.1 per cent respectively), and the subgroup of acute care surgeons (45.8 per cent), whereas resections performed by general surgeons were significantly associated with more frequent complications (odds ratio (OR) 2.5 (95 per cent c.i. 1.1 to 6.1)). The complication rate was numerically highest in patients operated on by surgeons with the highest resection volumes, which differed significantly from that of surgeons with intermediate resection volumes (OR 4.2 (95 per cent c.i. 1.1 to 16.0)). There was no difference in the mortality rate of patients operated on by surgeons with different specializations or yearly resection volumes.

**Conclusion:** This study documented similar morbidity and mortality rates after emergent colon resection performed by colorectal and acute care surgeons, but patients operated on by general surgeons had more frequent complications.

## Introduction

Colorectal cancer remains one of the most prevalent malignancies worldwide and a leading cause of cancer-related death[1]. The fact that up to 30 per cent of colorectal cancer patients present with acute symptoms due to mechanical obstruction or perforation is challenging as emergent colon resections are associated with significantly higher morbidity and mortality rates compared with elective surgery[2–4]. The relatively poor results after emergent colon resections may be explained by the fact that these patients generally are older, have a more advanced stage of disease, more frequently suffer from medical co-morbidities, and are in a poorer physiological condition[5].

There are many reports indicating that patients undergoing elective colon resections performed by surgeons who are specialized in colorectal surgery have lower morbidity rate and postoperative mortality rate than patients operated on by non-colorectal surgeons (NCS)[6,7]. Although there is no proof of a causal relationship between surgical specialization and better surgical outcome, it seems logical that frequent training and high volumes of elective surgery may result in fewer and less severe complications, and lower mortality rates. However, the advantageous results from elective procedures cannot automatically be extrapolated for emergent colon resections. The management of patients in need of emergent colon resections for cancer is more challenging than that of patients who undergo elective resections. It is therefore important that emergent colon cancer surgery is performed by surgeons who are appropriately trained. The first challenge is to manage the acute surgical problem in patients in a poor physiological condition due to perforations or mechanical obstructions to minimize the morbidity and mortality rates after surgery. The second challenge is to perform surgery with high oncological quality, to reduce the risk of local recurrence of disease and to achieve the best long-term survival for the patient. Theoretically, specialized colorectal surgeons (CS) may be better trained and have more experience in performing adequate oncological surgery with proper resection margins and adequate lymph node dissection. However, acute care surgeons (ACS) may have more experience in managing acute surgical problems in critically ill patients. As patients requiring emergent surgery for

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colon cancer need surgeons with a combination of these skills, the question of whether the qualification of surgeons with a certain specialization in general is better suited for this type of surgery arises. Although there are some reports suggesting that high-volume specialized CS have lower morbidity and mortality rates after emergent resections for colon cancer[8], there are numerous studies showing similar outcomes for patients having emergent colon resection performed by CS and NCS[9–14]. Thus, the importance and the effect of surgical specialization and surgeon resection volume on complications and mortality rate after emergent resections for colon cancer remain unclear.

The aim of this retrospective study was to evaluate and compare the effect of surgical specialization and surgeon resection volume on early postoperative outcome after emergent colon cancer resections at a secondary care hospital.

## Methods

### Study population

The study population consisted of patients who underwent emergent and elective resections for colon cancer between 2010 and 2020 at Helsingborg Hospital, Sweden, which is a secondary care hospital with a catchment area consisting of 350 000 residents. The patients were identified from the Swedish Colorectal Cancer Registry (SCRCR), which is a prospective and validated national registry with a coverage of 98.5 per cent for colon cancer[15]. Patients with a tumour located within 15 cm of the anal verge and cancer originating from the appendix were not included in the study. Demographic and clinical characteristics (patient sex, age, BMI, and ASA scores), tumour characteristics (TNM stage), surgical data (type of resection, resection margin status, operating time, intraoperative bleeding, and use of stoma), and data from the patients' post-operative course (intensive care unit (ICU) admission, length of hospital stay, and mortality rate) were extracted from the SCRCR. A retrospective manual review of the patients' medical records was conducted by three researchers to obtain additional clinical information (co-morbidity scores, indication for emergent surgery, if emergent resections were performed during or outside regular working hours, and the severity of complications according to the Clavien–Dindo classification), and to validate data from the SCRCR. To reduce the risk of information bias during data collection, the guidelines for retrospective medical record reviews were followed[16].

### Definitions

The Charlson co-morbidity index (CCI) was used to classify the co-morbidity burden of the patients[17]. The stage of colon cancer was categorized from I to IV according to the TNM classification[18]. Surgery was defined as emergent or elective. Emergent surgery was defined by procedures performed within 48 h after acute admission. As the timing of emergent surgery may affect postoperative outcome, a distinction was made between patients having emergent colon resections performed during ordinary working hours and those operated on during on-call hours. The latter were defined as having surgery outside regular working hours. Postoperative complications were characterized and categorized according to the Clavien–Dindo classification[19]. For the purpose of this study only Clavien–Dindo grades II to V were used. Complications were double-checked in medical records and in the SCRCR.

### Surgeons and surgical specialization

The most senior surgeon actively participating in each of the colon resections was noted and classified according to the surgical specialization. When resections were performed by more than one specialist in general surgery, which predominantly occurred during elective surgery, only the most senior surgeon of each procedure was utilized in the estimate. Colon resections performed for non-malignant disease and rectal cancer were not included in the calculation of the yearly resection volumes. Colorectal surgery is not recognized as an official surgical specialization in Sweden and CS were therefore defined as surgeons primarily working at the hospital's colorectal unit. For the purpose of this study, the surgeons were divided into groups based on their surgical specialization. First, all surgeons were divided into two groups consisting of CS and NCS. Secondly, the group of NCS was further divided into two groups, the first of which consisted of ACS who primarily work with trauma and non-trauma emergency surgery, and a second group consisting of board-certified general surgeons (GS) with additional specialization in upper gastrointestinal surgery or vascular surgery. The latter group of surgeons was for the purpose of this study defined as GS. Two separate analyses were made to assess the effect of surgical specialization on the outcome after emergent colon cancer resections. In the first analysis, the postoperative results were compared between groups of patients operated on by CS and NCS. In an additional analysis the postoperative outcomes were compared between groups of patients operated on by CS, ACS, and GS.

To assess the effect of surgeon colon cancer resection volumes on postoperative outcome, the surgeons were categorized into three groups based on the median and the 75th percentile of their annual resection volumes (elective and emergent) as the most senior surgeon.

### Outcomes of interest

The primary outcome of interest was the occurrence and the severity of postoperative complications according to the Clavien–Dindo classification[19]. The length of hospital stay, the need for reoperations and ICU care, the 30- and 90-day mortality rates, and the proportion of readmissions within 30 days of hospital discharge, as well as the types of surgical complications, were assessed and compared between patients operated on by surgeons with different specializations and different yearly resection volumes, as secondary aims.

### Statistics

Analysis of normality was carried out using the Kolmogorov–Smirnov test. As continuous data were not normally distributed, results are reported as medians and interquartile ranges (i.q.r.), and comparisons were made using non-parametric statistics. The Mann–Whitney *U* test was used to compare continuous data between individual groups and the Kruskal–Wallis test was used to compare multiple groups. Proportions were analysed using the chi-squared test. Logistic regression analysis was used to assess the influence of multiple factors on binary outcomes and is presented using odds ratio (OR) and 95 per cent c.i. Factors that were considered clinically important and believed to potentially effect outcome were entered simultaneously for adjustments in the regression model. Confidence intervals not including 1 and *P* values <0.050 were considered to represent statistical significance. All statistical analyses were performed

using SPSS® (IBM, Armonk, NY, USA; Version 25). The study was approved by the Swedish Ethical Review Authority (2019-04329).

## Results

### Study population

In total, 1121 patients underwent colon resections due to colon cancer at Helsingborg Hospital between 2010 and 2020. No patients with a need for emergent colon resection were referred to other hospitals and the postoperative care was provided at the hospital's unit for colorectal surgery. During the study interval, no patients with obstructing colon cancers were treated with colon stents as a bridge to elective surgery. After data validation, there were no missing data.

Of the colon resections, 886 (79.0 per cent) were elective and 235 (21.0 per cent) were emergent procedures. The emergent resections were performed by 30 different senior surgeons, of which 14 were classified as CS and 16 as NCS. The group of NCS consisted of five ACS and 11 GS. The median annual number of elective and emergent colon resections for cancer performed as the most senior surgeon was 4.1 (i.q.r. 1.2–8.4) per year. For comparison, when all cancer resections performed by the surgeons were included in the annual resection volumes, the total median number of resections was 8.9 (i.q.r. 2.3–18.5) per year. The median total annual resection volume for CS and NCS was 18.7 (i.q.r. 9.8–27.5) and 2.4 (i.q.r. 0.9–6.0) respectively. Ninety-nine (42 per cent) of the patients who underwent emergent surgery had colon resections performed by CS and in 136 (58 per cent) patients the resections were performed by NCS. Based on the median and 75th percentile of the total annual cancer resection volume as the most senior surgeon, 14 of the 30 surgeons had a median yearly resection volume of less than 4.11, and nine of the surgeons performed 4.11–8.40 colon resections for cancer per year. Seven surgeons, all of whom

**Table 1 Patient characteristics and descriptions of surgical procedures in patients who underwent emergent colon cancer resections performed by colorectal surgeons, acute care surgeons, and general surgeons**

| | Resections performed by | | | *P* |
|---|---|---|---|---|
| | Colorectal surgeons, *n* = 99 | Acute care surgeons, *n* = 107 | General surgeons, *n* = 29 | |
| **Age (years), median (i.q.r.)** | 76 (68–83) | 77 (66–84) | 81 (72–86) | 0.165 |
| **Sex** | | | | 0.892 |
| Male | 52 (52.5) | 54 (50.4) | 16 (55.2) | |
| Female | 47 (47.5) | 53 (49.5) | 13 (44.8) | |
| BMI (kg/m$^2$), median (i.q.r.) | 24.3 (21.9–27.5) | 23.8 (21.8–27.0) | 23.8 (21.3–28.0) | 0.819 |
| **ASA classification** | | | | |
| I | 10 (10.1) | 16 (15.0) | 2 (6.9) | 0.348 |
| II | 43 (43.4) | 48 (44.9) | 10 (34.5) | |
| III | 41 (41.4) | 38 (35.5) | 17 (58.6) | |
| IV | 5 (5.1) | 5 (4.7) | 0 (0.0) | |
| **Charlson co-morbidity index** | | | | |
| 2 | 48 (48.5) | 51 (47.7) | 9 (31.0) | 0.363 |
| 3 | 19 (19.2) | 20 (18.7) | 10 (34.5) | |
| 4 | 14 (14.1) | 9 (8.4) | 5 (17.2) | |
| 5 | 1 (1.0) | 2 (1.9) | 1 (3.4) | |
| 6 | 8 (8.1) | 19 (17.8) | 2 (6.9) | |
| 7 | 5 (5.1) | 4 (3.7) | 2 (6.9) | |
| ≥8 | 4 (4.0) | 2 (1.9) | 0 (0.0) | |
| **Indications for surgery** | | | | |
| Obstruction | 81 (81.8) | 89 (83.2) | 24 (82.8) | 0.592 |
| Perforation | 12 (12.1) | 11 (10.3) | 5 (17.2) | |
| Anaemia/bleeding | 6 (6.1) | 7 (6.5) | 0 (0) | |
| **Surgical procedures** | | | | |
| Right hemicolectomy | 50 (50.5) | 48 (44.9) | 13 (44.8) | 0.392 |
| Sigmoid resection | 15 (15.2) | 21 (19.6) | 2 (6.9) | |
| Colectomy | 14 (14.1) | 9 (8.4) | 6 (20.7) | |
| Left hemicolectomy | 10 (10.1) | 18 (16.8) | 2 (6.9) | |
| Hartmann's resection | 7 (7.1) | 7 (6.5) | 5 (17.2) | |
| Transverse colon resection | 2 (2.0) | 3 (2.8) | 1 (3.4) | |
| Low anterior resection | 1 (1.0) | 1 (0.9) | 0 (0) | |
| Resections outside regular working hours | 39 (39.4) | 38 (35.5) | 15 (51.7) | 0.284 |
| Operating time (min), median (i.q.r.) | 180 (150–241) | 187 (151–230) | 196 (150–240) | 0.963 |
| Perioperative bleeding (ml), median (i.q.r.) | 200 (100–300) | 100 (50–200) | 300 (150–325) | 0.008 |
| Lymph node yield, median (i.q.r.) | 27 (21–38) | 26 (20–36) | 28 (21–40) | 0.663 |
| Lymph node yield >12 | 95 (96.0) | 103 (96.3) | 28 (96.6) | 0.987 |
| $R_1$ resections | 6 (6.1) | 1 (0.9) | 1 (3.4) | 0.128 |
| **Stoma formation*** | | | | |
| Permanent stoma | 21/52 (40.4) | 30/60 (50.0) | 10/16 (62.5) | 0.266 |
| Protective stoma | 6/52 (11.5) | 2/60 (3.3) | 0/16 (0.0) | 0.110 |
| Any stoma | 27/52 (51.9) | 32/60 (53.3) | 10/16 (62.5) | 0.754 |
| **Tumour stage** | | | | |
| I | 2 (2.0) | 0 (0) | 0 (0) | 0.601 |
| II | 38 (38.4) | 42 (39.3) | 8 (27.6) | |
| III | 45 (45.5) | 49 (45.8) | 17 (58.6) | |
| IV | 14 (14.1) | 16 (15.0) | 4 (13.8) | |

Values are *n* (%) unless otherwise indicated. i.q.r., interquartile range. *Only patients with left-sided tumours included in analysis.

were specialized CS, had a median yearly rate of colon cancer resections exceeding 8.40 per year.

## Outcomes associated with surgical specialization

Clinical characteristics and descriptions of the surgical procedures of patients who underwent emergent resections performed by CS and NCS are shown in *Table S1*. The median age and BMI, the sex distribution, and the co-morbidity burden were similar in the two groups of patients. There was no difference in the indications for emergent colon resections and the type of surgical procedure performed was similar in patients operated on by CS and NCS. Furthermore, there was no difference in the median operating time, the perioperative blood loss, the number of resected lymph nodes, or the tumour stage between the two groups of patients. The proportion of $R_1$ resections was numerically lower for patients operated on by NCS, but the difference did not quite reach statistical significance. This was further examined in an adjusted regression analysis, but no significant association between $R_1$ resections and colon resections performed by CS was found. In patients with left-sided cancers, the proportion of protective stomas was significantly higher in patients operated on by CS. The frequency and the severity of complications according to the Clavien–Dindo classification was similar in patients operated on by CS and NCS (*Table S2*). The rate of reoperations due to anastomotic leakage in patients operated on by CS and NCS was comparable (3.0 *versus* 2.9 per cent respectively, $P = 0.968$). Similarly, there was no difference in the proportions of patients with intra-abdominal abscesses (3.0 *versus* 1.5 per cent respectively, $P = 0.423$), patients with wound site infections (9.1 *versus* 7.4 per cent respectively, $P = 0.641$), or patients who were reoperated on due to wound dehiscence (4.0 *versus* 2.9 per cent respectively, $P = 0.646$). Furthermore, the length of hospital stay, the frequency of reoperations, the need for ICU postoperative care, and the rates of 30- and 90-day mortality rate were similar in the two groups of patients. However, unplanned hospital readmissions were significantly more frequent in patients operated on by NCS, which was demonstrated by an adjusted OR that was 4.2 times higher than that of patients operated on by CS.

In the data collection and validation process, it was observed that 176 of the 1121 (15.7 per cent) patients who underwent colon resections were misclassified regarding the presence or absence of complications. Of these patients, no complications were registered in the SCRCR, but were present according to the medical records in 152 (86.4 per cent) patients. Conversely, complications were registered in the SCRCR in 24 patients (13.6 per cent), but uneventful postoperative courses without complications were documented in the medical records. In the analysis of postoperative outcome in patients operated on by CS, ACS, and GS, there was no significant difference in the patient characteristics, the indications for emergent surgery, or the types of surgical procedures (*Table 1*). There was a significant difference in the estimated perioperative blood loss, with the highest numerical volume for GS, whereas the operating time, the tumour stage, and the indicators of adequate oncological surgery were similar in patients operated on by the three groups of surgeons. The proportion of complications was numerically lowest in patients operated on by ACS, but the difference did not quite reach statistical significance (*Table 2*). In a complementary binary regression analysis, there was a significant association between complications and emergent colon resection performed by GS, with an adjusted OR that was 2.5 times higher than that of ACS (*Table 2*). No such association was found for patients operated on by CS. The distribution of complications according to the Clavien–Dindo classification was similar in the three groups of patients. The proportion of patients who needed ICU care was numerically lowest for patients operated on by ACS, but there was no significant difference between the groups. The duration of hospital stay was similar in groups of patients operated on by CS, ACS, and GS, but the rate of reoperations differed significantly. Compared with patients operated on by ACS, who had the numerically lowest proportion of reoperations, a binary regression analysis showed a significant association between reoperations and colon resections performed by GS, but no such association was found for resections performed by CS. Similarly, the proportion of unplanned hospital readmissions differed significantly between the three groups of patients. A complementary adjusted binary regression analysis showed a significant association between

**Table 2 Postoperative complications and outcome after emergent colon cancer resections performed by colorectal surgeons, acute care surgeons, and general surgeons**

| | Resections performed by | | | *P* |
|---|---|---|---|---|
| | Colorectal surgeons *n* = 99 | Acute care surgeons *n* = 107 | General surgeons *n* = 29 | |
| **Clavien–Dindo classification of complications** | | | | |
| No complication | 45 (45.5) | 58 (54.2) | 9 (31.0) | 0.349 |
| II | 33 (33.3) | 29 (27.1) | 11 (37.9) | |
| III | 10 (10.1) | 7 (6.5) | 5 (17.2) | |
| IV | 7 (7.1) | 6 (5.6) | 1 (3.4) | |
| V | 4 (4.0) | 7 (6.5) | 3 (10.3) | |
| **Any complication** | 54 (54.5) | 49 (45.8) | 20 (69.0) | 0.073 |
| Regression analysis*, OR (95% c.i.) | 1.4 (0.8,2.4) | Reference | 2.5 (1.1,6.1) | – |
| ICU care | 18 (18.2) | 10 (9.3) | 4 (13.8) | 0.181 |
| **Reoperations** | 12 (12.1) | 6 (5.6) | 6 (20.7) | 0.042 |
| Regression analysis*, OR (95% c.i.) | 2.3 (0.7,6.8) | Reference | 4.2 (1.1,16.0) | – |
| Length of hospital stay (days), median (i.q.r.) | 13 (9–22) | 12 (8–16) | 15 (8–32) | 0.105 |
| **Readmissions†** | 4/95 (4.2) | 12/100 (12.0) | 6/26 (23.1) | 0.011 |
| Regression analysis*, OR (95% c.i.) | Reference | 3.5 (1.1,11.6) | 7.0 (1.7,29.2) | – |
| 30-day mortality rate | 3 (3.0) | 7 (6.5) | 3 (10.3) | 0.262 |
| 90-day mortality rate | 8 (8.1) | 7 (6.5) | 3 (10.3) | 0.775 |

Values are *n* (%) unless otherwise indicated. OR, odds ratio; ICU, intensive care unit; i.q.r., interquartile range. *Binary regression analysis with adjustments for ASA classification, tumour stage, indication for emergent surgery, and surgery performed outside regular working hours. †Patients with in-hospital mortality rate excluded from analysis.

**Table 3 Patient characteristics and description of surgical procedures in patients who underwent emergent colon cancer resections performed by surgeons with varying median yearly resection volumes**

| | Surgeons performing | | | P |
|---|---|---|---|---|
| | <4.11 resections/year (*n* = 80) | 4.11–8.40 resections/year (*n* = 96) | >8.40 resections/year (*n* = 59) | |
| **Sex** | | | | 0.190 |
| Male | 45 (56.3) | 43 (44.8) | 34 (57.6) | |
| Female | 35 (43.8) | 53 (55.2) | 25 (42.4) | |
| Age (years), median (i.q.r.) | 78 (66–83) | 78 (66–83) | 76 (70–83) | 0.501 |
| BMI (kg/m$^2$), median (i.q.r.) | 23.9 (21.5–27.4) | 23.8 (22.0–26.7) | 24.8 (21.9–27.7) | 0.758 |
| **ASA classification** | | | | |
| I | 10 (12.5) | 13 (13.5) | 5 (8.5) | 0.609 |
| II | 30 (37.5) | 41(42.7) | 30 (50.8) | |
| III | 38 (47.5) | 37 (38.5) | 21 (35.6) | |
| IV | 2 (2.5) | 5 (5.2) | 3 (5.1) | |
| **Charlson co-morbidity index** | | | | |
| 2 | 31 (38.8) | 48 (50.0) | 29 (49.2) | 0.103 |
| 3 | 18 (22.5) | 21 (21.9) | 10 (16.9) | |
| 4 | 9 (11.3) | 7 (7.3) | 12 (20.3) | |
| 5 | 3 (3.8) | 1 (1.0) | 0 (0.0) | |
| 6 | 14 (17.5) | 12 (12.5) | 3 (5.1) | |
| 7 | 5 (6.3) | 4 (4.2) | 2 (3.4) | |
| ≥8 | 0 (0) | 3 (3.1) | 1 (1.7) | |
| **Indications for emergent surgery** | | | | |
| Bowel obstruction | 63 (78.8) | 82 (85.4) | 49 (83.1) | 0.481 |
| Perforation | 12 (15.0) | 11 (11.5) | 5 (8.5) | |
| Anaemia/bleeding | 5 (6.3) | 3 (3.1) | 5 (8.5) | |
| **Surgical procedures** | | | | |
| Right hemicolectomy | 42 (52.5) | 44 (45.8) | 25 (42.4) | 0.643 |
| Colectomy | 8 (10.0) | 10 (10.4) | 11 (18.6) | |
| Hartmann's resection | 9 (11.3) | 6 (6.3) | 4 (6.8) | |
| Sigmoid resection | 8 (10.0) | 21 (21.9) | 9 (15.3) | |
| Left hemicolectomy | 10 (12.5) | 12 (12.5) | 8 (13.6) | |
| Transverse colon resection | 2 (2.5) | 2 (2.1) | 2 (3.4) | |
| Low anterior resection | 1 (1.3) | 1 (1.0) | 0 (0) | |
| Resections outside regular working hours | 36 (45.0) | 32 (33.3) | 24 (40.7) | 0.277 |
| Operating time (min), median (i.q.r.) | 196 (143–229) | 182 (150–239) | 182 (155–245) | 0.907 |
| Bleeding (ml), median (i.q.r.) | 175 (50–300) | 150 (100–250) | 200 (100–300) | 0.968 |
| **Stoma formation*** | | | | |
| Protective stoma | 2/39 (5.1) | 3/52 (5.8) | 3/37 (8.1) | 0.851 |
| Permanent stoma | 23/39 (59.0) | 26/52 (50.0) | 12/37 (32.4) | 0.062 |
| Any stoma | 25/39 (64.1) | 29 (55.8) | 15 (40.5) | 0.113 |
| Lymph node yield, median (i.q.r.) | 28 (21–36) | 26 (18–38) | 28 (20–37) | 0.609 |
| Lymph node yield >12 | 79 (98.8) | 91 (94.8) | 56 (94.9) | 0.334 |
| **$R_1$ resections** | 2 (2.5) | 1 (1.0) | 5 (8.5) | 0.040 |
| Regression analysis†, OR (95% c.i.) | 0.2 (0.0,1.5) | 0.1 (0.0,1.1) | Reference | – |
| **Tumour stage** | | | | |
| I | 1 (1.3) | 0 (0) | 1 (1.7) | 0.773 |
| II | 30 (37.5) | 33 (34.4) | 25 (42.4) | |
| III | 37 (46.3) | 47 (49.0) | 27 (45.8) | |
| IV | 12 (15.0) | 16 (16.7) | 6 (10.2) | |

Values are *n* (%) unless otherwise indicated. i.q.r., interquartile range; OR, odds ratio. *Only patients with left-sided tumours included in analysis. †Binary regression analysis with adjustments for tumour stage, indication for emergent surgery, and resections performed outside regular working hours.

readmissions and emergent colon resections performed by ACS and GS, with ORs that were 3.5 and 7 times higher respectively than that of patients operated on by CS. There was no difference in the 30- or 90-day mortality rate of patients operated on by the three groups of surgeons.

## Outcomes associated with surgeon resection volumes

The patient characteristics and the co-morbidity burden were similar in patients operated on by the three groups of surgeons with different median yearly resection volumes (*Table 3*). Similarly, the distribution of indications for emergent surgery, the types of colon resections performed, and the median operating time were similar in these groups of patients. There was no difference in tumour stage or the median number of harvested lymph nodes, but the proportion of $R_1$ resections differed significantly, with the numerically highest value for surgeons with the highest annual resection volume. However, an adjusted binary logistic regression analysis showed no significant association between resection volumes and $R_1$ resections. There was a significant difference in the proportion of complications, with the numerically highest complication rate in patients operated on by surgeons with the highest resection volumes (*Table 4*). Adjusted binary regression analysis confirmed significantly lower odds for complications in patients operated on by surgeons with medium resection volumes, but no such difference was observed for patients operated on by surgeons with the lowest annual resection volumes. The median length of hospital stay, the proportion of reoperations, the need for ICU postoperative care, and the proportion of postoperative

**Table 4 Postoperative complications and outcome in patients who underwent colon resections performed by surgeons with varying median yearly resection volumes**

| | Surgeons performing | | | P |
|---|---|---|---|---|
| | <4.11 resections/year (*n* = 80) | 4.11–8.40 resections/year (*n* = 96) | >8.40 resections/year (*n* = 59) | |
| **Clavien–Dindo classification of complications** | | | | |
| No complication | 35 (43.8) | 58 (60.4) | 19 (32.2) | 0.029 |
| II | 24 (30.0) | 25 (26.0) | 24 (40.7) | |
| III | 11 (13.8) | 3 (3.1) | 8 (13.6) | |
| IV | 4 (5.0) | 5 (5.2) | 5 (8.5) | |
| V | 6 (7.5) | 5 (5.2) | 3 (5.1) | |
| **Any complication** | 45 (56.3) | 38 (39.6) | 40 (67.8) | 0.002 |
| Regression analysis*, OR (c.i.) | 0.6 (0.3,1.2) | 0.3 (0.1,0.6) | Reference | – |
| Reoperations | 11 (13.8) | 5 (5.2) | 8 (13.6) | 0.109 |
| ICU care | 11 (13.8) | 11 (11.5) | 10 (16.9) | 0.625 |
| Length of hospital stay (days), median (i.q.r.) | 12 (8–22) | 12 (8–18) | 14 (10–24) | 0.089 |
| **Readmissions†** | 14/74 (18.9) | 6/91 (6.6) | 2/56 (3.6) | 0.006 |
| Regression analysis*, OR (c.i.) | 6.4 (1.3,30.5) | 1.8 (0.3,9.8) | Reference | – |
| 30-day mortality rate | 6 (7.5) | 4 (4.2) | 3 (5.1) | 0.619 |
| 90-day mortality rate | 6 (7.5) | 7 (7.3) | 5 (8.5) | 0.962 |

Values are *n* (%) unless otherwise indicated. OR, odds ratio; ICU, intensive care unit; i.q.r., interquartile range. *Binary regression analysis with adjustments for ASA classification, tumour stage, indication for emergent surgery, and surgery performed outside regular working hours. †Patients with in-hospital mortality rate excluded from analysis.

mortality rate were similar in patients having their colon resections performed by surgeons with different yearly resection volumes. The proportion of unplanned hospital readmissions, however, differed significantly between the three groups of patients, with almost 19 per cent readmissions in the group of patients operated on by surgeons with the lowest yearly resection volumes. Compared with surgeons with the highest yearly resection volumes, the adjusted OR for unplanned readmissions was six times higher for patients operated on by surgeons with the lowest resection volumes; however, no such difference was observed for the group of patients operated on by surgeons with intermediate resection volumes.

## Discussion

This study assessed the influence of surgical specialization and surgeon resection volume in patients who underwent emergent resections for colon cancer. The main observation was that emergent resections for colon cancer were performed with similar quality by CS and NCS, especially ACS, with equivalent oncological quality and similar rates of complications and postoperative mortality rate. GS appear to have less favourable results, with more frequent postoperative complications, reoperations, and readmissions.

The proportion of postoperative complications after emergent colon cancer resections in the present study was 52 per cent, which is similar to the complication rates reported in previous studies[5,8,10,13,20]. Although the SCRCR is a validated registry, the observation regarding misclassification of complications in the cohort suggests that studies based on national or regional registries may be burdened with errors in the detection and registration of complications. Consequently, comparisons of complications between studies should be made with caution. The complication rates of patients operated on by NCS, and the subgroup of ACS, were equivalent to that of patients operated on by CS. However, surgeons who do not primarily work in colorectal or acute care surgery had significantly more complications, which was suggested by an adjusted OR that was 2.5 times higher than that of ACS. It is possible that the less advantageous outcome for patients operated on by GS is a result of less frequent exposure to both colorectal and emergent surgery.

The proportion of complications differed significantly in patients operated on by surgeons with various annual resection volumes, and surprisingly the numerically highest complication rate was observed for surgeons with the highest resection volumes. This observation was not explained by differences in clinical features of patients or the surgical procedures, as the adjusted OR for complications differed significantly in comparison with surgeons with intermediate resection volumes.

The observed mortality rates in the present study were similar to those reported for specialized CS at tertiary centres[8,13], high-volume centres[14,21], and centres that fulfil national caseload requirements[22], suggesting that emergent resections for colon cancer can be safely performed at secondary care hospitals. This is important, as most studies on the effect of surgical specialization and resection volume are conducted at large tertiary centres, but, in Sweden, and possibly also in many other countries, the vast majority (80 per cent) of colon cancer resections are performed at secondary care hospitals[15]. The proportion of postoperative mortality rate in the present study was equivalent in patients operated on by CS and NCS, and the subgroup of patients operated on by ACS. The mortality rate of patients operated on by GS was numerically higher, but did not differ significantly compared with patients operated on by CS and ACS. Furthermore, the mortality rates were similar in patients operated on by surgeons with different annual resection volumes.

For policymakers and healthcare institutions, elimination of variations in healthcare quality represents a matter of significant interest. As several studies report a superior outcome among patients undergoing elective surgery in high-volume surgical units by surgeons who perform a large number of procedures[7,23–25], this has led to an increasing centralization of colorectal surgery to high-volume centres[26]. Although morbidity and mortality rates after elective colon resections are lower in patients operated on at high-volume centres or by specialized surgeons with a high caseload, extrapolating the outcome from elective surgical cases to emergent surgical cases is inadequate. This is due to the fact that the surgical management of patients who are critically ill, and in a poor physiological condition, is a different and a more complex

challenge. Additional surgical skills need to complement those required for elective oncological surgery to achieve good postoperative results after emergent resections. Although there are reports proposing that high-volume specialized CS have lower morbidity and mortality rates after emergent resections for colon cancer[8], there are several studies that support the observations in our study, suggesting similar outcomes for patients having emergent colon resection performed by CS and NCS[9–14].

The indicators of quality for oncological surgery such as lymph node yield and $R_0$ resections were similar in patients undergoing emergent colon resections performed by CS and NCS. This suggests that the quality in oncological surgical technique was equally good regardless of surgical specialization, but studies of long-term and cancer-free survival would be needed to confirm this observation.

The proportions of readmissions and re-interventions after colon cancer surgery may be useful indicators of the quality of surgical care. In the present study, the proportion of reoperations was lowest in patients operated on by ACS, which differed significantly from that of patients operated on by GS. The overall rate of 30-day readmissions in the present study was 8.5 per cent, which compares favourably with other reports on unplanned readmissions after emergent colorectal surgery[27,28]. Compared with CS, the adjusted ORs for readmissions were significantly higher in patients operated on by NCS, and the subgroup of patients operated on by GS, but no such difference was observed for patients operated on by ACS. Furthermore, there was a significant association between unplanned readmissions and colon resections performed by surgeons with the lowest annual resection volume. The reason for the large differences in readmissions is unknown, but possibly represents differences in patient characteristics[29] or the general quality of care rather than in the quality of the surgical procedure itself, although reports have concluded that the readmission rate is a poor proxy for quality of care[30]. Previous studies have suggested that 30-day readmissions are strongly associated with postoperative complications[31], but this hypothesis was not confirmed by the observations in the present study, as patients operated on by ACS had the numerically lowest rate of complications, but a rate of unplanned readmissions that was significantly higher than that of patients operated on by CS. Furthermore, it has been suggested that the main reason for unplanned readmissions is occurrences that happen after discharge[32], which makes them difficult to predict and prevent.

The effect of surgical specialization should ideally be studied in well designed randomized controlled studies, but such studies would be difficult to perform. Bias due to timing of the surgical procedure caused by differences in the severity of the condition of the patients may significantly affect the outcome of emergent colon cancer resections. The most critically ill patients will require immediate surgery, even during the night, when a CS may not be available at many surgical units. Furthermore, less critically ill patients can often wait until the following morning and have emergent resections performed by a CS. Thus, it is possible that CS manage less critically ill patients and may therefore in some studies have more favourable postoperative outcomes than surgeons with other specialties. This perception is supported by a study from a tertiary centre in Norway. They reported that only 7 per cent of emergent colorectal cancer resections were performed by specialized gastrointestinal surgeons at night, which was significantly lower than the proportion of emergent resections performed by this group of surgeons during the day[33].

It is often problematic to interpret the effect of surgical specialization and resection volumes on postoperative outcome, as studies are heterogeneous and include various proportions of patients with rectal cancer and/or benign disease. The homogeneity of the study population in the present study with no patients with rectal cancer or benign disease is therefore a strength. Another strength is that the study was conducted at a secondary care hospital. As the majority of colon cancer resections in Sweden are performed at secondary care hospitals, it is important to be able to compare results with those from tertiary high-volume centres. The limitations of the study include its retrospective nature, with such studies generally being inferior to prospective trials regarding precision and validity. Another potential limitation is the single-centre cohort study design, as local variations within the groups of surgeons and differences in the patient selection or indications for emergent surgery may influence the generalizability, and comparisons with other studies must therefore be made with caution. Additionally, a potential limitation of all similar studies is that the definitions of surgical specializations may vary. Consequently, conclusions may not be universal, and comparisons have to be made cautiously. In Sweden, colorectal surgery is not a formally acknowledged specialty, but all CS in the present study work at the departments' colorectal unit and manage patients with colon cancer daily. Many of the surgeons in the present study do rotations at the colorectal and the acute care units, which may contribute to the comparably good results. Another limitation is that the group of patients who underwent emergent colon resections performed by general surgeons, was a relatively small and heterogenic group, and conclusions regarding these results should be made with caution.

Based on the observations in this study it can be summarized that emergent resections for colon cancer can be performed at secondary care hospitals, with complication and mortality rates comparable to those of tertiary high-volume units. Furthermore, in comparison with specialized CS, emergent colon resections were performed with equivalent quality by NCS, especially ACS, with similar rates of morbidity and mortality and similar oncological quality. Patients having colon resections for cancer performed by GS had a less favourable postoperative outcome, with more frequent complications, reoperations, and unplanned readmissions, possibly due to less frequent exposure of GS to both colorectal and emergent surgery. To improve postoperative morbidity and mortality rates for patients undergoing emergent colon resections for cancer, regular rotations at colorectal and acute care units for surgeons performing emergent surgery may be needed to achieve and maintain competence in colorectal and acute care surgery.

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## Disclosure

The authors declare no conflict of interest.

## Supplementary material

Supplementary material is available at *BJS Open* online.

## Data availability

Due to their proprietary nature and ethical concerns, supporting data cannot be made openly available. Further information

about the data and conditions for access are available from the authors on request.

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# Paper II

*Original Article*

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# Impact of surgical specialization on long-term survival after emergent colon cancer resections

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**Abstract**

**Background:** The impact of surgical specialization on long-term survival in patients undergoing emergent colon cancer resections remains unclear.

**Method:** A retrospective analysis was conducted on all patients who underwent emergent colon cancer resections at a secondary care hospital between 2010 and 2020. The most senior surgeon performing the procedures was classified as colorectal surgeon (CS) or non-colorectal surgeon (NCS). NCS was further divided into acute care surgeons (ACSs) or general surgeons (GSs). Overall survival (OS) and cancer-free survival (CFS) were compared in patients operated by surgeons with different specializations.

**Results:** A total of 235 emergent resections were performed during the study period, of which 99 (42%) were performed by CS and 136 (58%) by NCS. In adjusted Cox regression analyses, OS and CFS were similar in patients operated on by CS and NCS (hazard ratio (HR) for OS: 1.02 (0.72–1.496), $p = 0.899$ and HR for CFS: 0.91 (0.61–1.397), $p = 0.660$). Similarly, OS and CFS were equivalent in patients operated by ACS and CS (HR for OS: 1.10 (0.75–1.62), $p = 0.629$ and HR for CFS: 1.24 (0.80–1.92), $p = 0.343$). However, patients operated by GS had significantly shorter OS and CFS (HR for OS: 1.78 (1.05–3.00), $p = 0.031$ and HR for CFS: 1.83 (1.02–3.26), $p = 0.041$) compared with those operated by ACS and CS.

**Conclusion:** Long-term survival after emergent colon cancer resections was similar in patients operated on by CS and NCS, and the subgroup of ACS, indicating equivalent comparable surgical quality. The less favorable poorer survival observed for patients operated on by GS may possibly be due to less frequent exposure to colorectal and emergent surgery.

**Keywords**

Long-term outcome, overall survival, cancer-free survival, emergency colon resection, colon cancer, surgeon specialization

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## Introduction

Colorectal cancer is the second most common cancer worldwide, accounting for 10% of global cancer incidence and 9.4% of cancer-related deaths.[1] Surgical resection remains the only curative treatment for colon cancer, with 70%–80% of patients being suitable for resection with curative intent.[2] Many patients with colon cancer initially have vague or no symptoms, and up to 30% of patients present late often with emergent symptoms due to mechanical obstruction or perforation.[3–5]

The high proportion of patients in need of emergent surgery is a significant challenge, as these individuals tend to have less favorable outcomes

with more frequent and severe complications, higher postoperative mortality, and shorter long-term survival compared with patients undergoing elective resections.[3–8] The relatively poor outcomes following emergent resections are often attributed to patient-related factors, as these patients typically are older, have more comorbidities, present with more advanced tumor stages, and are in worse physiological condition than those undergoing elective procedures.[9]

In addition to patient-related factors, growing evidence suggests that surgeon-related factors—such as surgical experience and surgical specialization—may influence postoperative outcomes.[10–13] Several studies have shown superior short- and long-term results after for elective colon resections performed by colorectal surgeons (CSs) compared with those of non-colorectal surgeons (NCS).[11,12,14,15] However, the management of patients requiring emergent surgery due to mechanical obstruction or perforation is more complex, and the surgical challenge is substantially greater than that of elective resections. Some studies of emergent colon cancer resections report fewer complications and lower postoperative mortality in patients operated by CS,[16] but most studies, including one recently published by our group,[17] report similar morbidity and mortality rates in patients operated by CS and NCS. These observations suggest that the quality of emergent colon resections performed by CS and NCS generally is equivalent.[18–22]

In sharp contrast to the relative abundance of studies comparing short-term outcomes following emergent colon cancer resections performed by surgeons of different specializations, there is scarcity of reports on long-term survival outcomes. To our knowledge, the only available study reported that patients undergoing emergent colon resections performed by CS had significantly higher 5-year survival rates compared with those operated on by NCS.[2]

The lack of reports on long-term outcomes following emergent resections for colon cancer performed by surgeons with different specializations stimulated us to conduct this retrospective study. The primary aim was to compare the effect of surgical specialization on overall survival (OS) and cancer-free survival (CFS) in patients undergoing emergent colon cancer resections at a secondary care hospital.

## Methods

### Study population

This retrospective study included patients aged 18 years and older who underwent resections for colon cancer at Helsingborg hospital between 2010 and 2020. The Swedish Colorectal Cancer Registry (SCRCR) was used to identify patients and extract demographic and clinical data. The SCRCR is a nationwide, prospective registry for colorectal cancer with near-complete coverage.[23] Patients operated for appendiceal neoplasms or rectal cancer were excluded from the study. Medical records for each patient were reviewed to obtain additional clinical information and validate the data from the registry. Retrospective medial record review guidelines were followed to minimize information bias during data collection.[24]

Colon cancer staging was based on the Tumor-Node-Metastasis (TNM) classification system.[25] Unplanned colon resections performed within 48 h of acute admission were classified as emergent, while all other procedures were classified as elective. Emergent resections performed between 5:00 pm and 7:00 am were considered nighttime surgeries, while those performed during the remaining hours were classified as daytime surgeries. Postoperative care and follow-up were managed by the hospital's colorectal surgery unit. Postoperative treatment and follow-up were determined at multidisciplinary tumor board conferences (MDT). All patients participated in a standard follow-up program, which included computed tomography scans at 1 and 3 years post-surgery, and colonoscopy 3 years after surgery. Long-term oncological outcomes, including locoregional and systematic recurrence, were recorded. Patients were followed until death or for a maximum of 5 years postoperatively.

### Surgeons and surgical specialization

The overall surgical experience of the surgeons was assessed by calculating the time from their board certification in general surgery to the date of surgery for each resection. Information regarding the date of board certification was obtained from the Swedish National Board of Health and Welfare for each surgeon. In cases where more than one board-certified surgeon actively participated in the procedure, the most senior surgeon was identified based on their time from board certification to the date of the resection. Surgeons were categorized into two groups based on their surgical specialization: CSs and NCSs. The NCS group was further subdivided into two categories: acute care surgeons (ACSs) and general surgeons (GSs). For this study, GS included all board-certified surgeons with other specializations than CS or ACS. In Sweden, colorectal surgery and acute care surgery are not recognized official as surgical specializations. Therefore, CS were defined as surgeons regularly working at the hospital's colorectal unit, while ACS referred to surgeons regularly working at the unit for trauma and emergency surgery.

### Statistics

The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. Since the data were not normally distributed, results were presented as medians and $25^{th}$–$75^{th}$ percentiles. The Mann–Whitney *U*-test was used to compare continuous variables between two groups, and the Kruskal–Wallis test was used for comparisons among multiple groups. Categorical variables were presented as numbers and percentages, and differences between groups were analyzed using the Chi-square test.

Kaplan–Meier curves were used to describe the OS and CFS, and comparisons between groups were made using the log rank test. OS was plotted from the day of surgery, counting deaths as events and the remainders as censored as of the last day of follow-up. Similarly, in patients without macroscopically eveident generalized cancer, CFS was plotted counting cancer reccurence or deaths as events and the rest as censored.

Cox regression analyses were performed to assess the effects of multiple variables and adjust for potential confounding factors influencing survival. Adjustments for patient age, gender, ASA classification, tumor stage, overall surgical experience, indication for emergent surgery, nighttime surgery, and adjuvant chemotherapy were entered simultaneously in the regression models. A p-value of less than 0.05 was considered statistically significant.

All statistical analyses were performed using the IBM SPSS® Statistics version 25 (IBM Corp., Armonk, NY, USA). The study was approved by the Swedish Ethical Review Authority (2019-04329).

## Results

### Study population

Between 2010 and 2020, a total of 1121 patients underwent colon resections for colon cancer at Helsingborg hospital. Of these, 235 (21%) patients underwent emergent procedures. No patients requiring emergent surgery were referred to other hospitals, and the use of stents as a bridge to elective surgery was not employed during the study period. A laparoscopic approach was used in two (1%) patients, while the remaining patients underwent conventional open surgery. Following data validation, there were no missing data.

All emergent resections were performed by 30 senior board-certified surgeons, of whom 14 were classified as CS and 16 as NCS. The NCS group consisted of 5 ACSs and 11 GSs. Ninety-nine (42%) of the emergent resections were performed by CS, and 136 (58%) of the resections were performed by NCS, of which 107 (79%) were performed by ACS and 29 (21%) by GS.

The median number of annual colon cancer resections performed by CS was significantly higher than that performed by NCS (18.7 (9.1–27.5) versus 2.4 (0.9–5.98), $p < 0.001$). However, the median overall surgical experience was similar between the two groups of surgeons (CS: 10.5 years (7.2–20.7) versus NCS: 14.0 years (6.5–20.9), $p = 0.790$). The annual resection volumes of ACS (5.9 (3.2–12.2)) and GS (1.6 (0.9–5.4)) were significantly lower than those of CS ($p < 0.001$), but there was no difference in overall surgical experience among the three groups of surgeons: CS (10.5 (7.2–20.7) years), ACS (16.0 (8.0–20.5) years), and GS (14.0 (5.0–21.5) years; $p = 0.889$).

The median follow-up for all patients was 3.6 years, ranging from 0.0 to 5 years. The median follow-up for patients who died was 1.5 years (range 0.0–4.99 years), while the median follow-up for patients who did not die during through the 5-year follow-up was 5.0 years (range 2.4–5 years).

### Outcomes associated with surgical specialization

Patient demographics, including age, gender, ASA class, and the indications for emergent surgery, were similar across the different surgeon specialization groups in patients who underwent colon resections performed by surgeons with different specializations (Tables 1 and 2). Similarly, the types of colon resections, the proportion of nighttime resections, and the proportion of patients treated with adjuvant chemotherapy were equivalent in all groups of patients. In comparison with patients operated by CS, the number of resected lymph nodes and tumor stages were similar in patients operated by CS and those operated by NCS, including the subgroups classified as ACS and GS.

The cumulative OS and CFS was similar in patients who underwent emergent colon cancer resections performed by CS and NCS (Figs 1 and 2). This observation was confirmed by Cox regression analyses with adjustments for factors perceived as clinically relevant confounders (hazard ratio (HR) for OS: 1.02 (0.72–1.46), $p = 0.899$; HR for CFS: 0.91 (0.61–1.37), $p = 0.660$).

However, the cummulative OS and CFS differed significantly in patients operated by CS, ACS, and GS, with similar survival curves for patients operated by CS and ACS, but with less advantageous survival in patients operated by GS (Figs 3 and 4). Complementary adjusted Cox regression analyses revealed no differences in OS or CFS between patients operated by ACS and CS (HR for OS: 1.10 (0.75–1.62), $p = 0.629$; HR for CFS: 1.24 (0.80–1.92), $p = 0.343$). In contrast, resections performed by GS were significantly associated with shorter OS and CFS, with adjusted HRs nearly twice as high as those for ACS and CS (HR for OS: 1.78 (1.05–3.00), $p = 0.031$ and HR for OS 1.83 (1.02–3.26), $p = 0.041$).

## Discussion

This study assessed the influence of surgical specialization on long-term outcomes after emergent resections for colon cancer. The primary observation was that the number of harvested lymph nodes, the proportion of R0 resections, OS, and CFS were similar in patients operated on by CSs and NCSs, including the subgroup of ACSs. The results suggest that oncological quality of resections performed by ACSs and CS was equivalent. However, patients operated on by GSs had less favorable long-term outcomes, with shorter OS and CFS.

It is well established that patients undergoing elective colon resections for cancer performed by specialized CS experience lower morbidity and postoperative mortality compared with those operated on by NCS.[11,13–15] This has contributed to an increasing centralization of colorectal surgery to high-volume centers.26 However, the management of patients requiring emergent colon resections for cancer is more challenging than that of patients who undergo elective procedures , and the favorable outcomes for patients operated

**Table 1.** Patient characteristics and descriptions of surgical procedures in patients who underwent emergent colon cancer resections performed by colorectal and non-colorectal surgeons.

| | Resections performed by | | *p*-value |
|---|---|---|---|
| | Colorectal surgeons, *n* = 99 | Non-colorectal surgeons, *n* = 136 | |
| Age (years) | 76 (68–83) | 77 (68–84) | 0.659 |
| Gender (female/male) | 47/52 | 66/70 | 0.873 |
| ASA classification | | | |
| I | 10 (10.1%) | 18 (13.2%) | 0.862 |
| II | 43 (43.4%) | 58 (42.6%) | |
| III | 41 (41.4%) | 55 (40.4%) | |
| IV | 5 (5.1%) | 5 (3.7%) | |
| Indications for surgery | | | |
| Obstruction | 81 (81.8%) | 113 (83.1%) | 0.941 |
| Perforation | 12 (12.1%) | 16 (11.8%) | |
| Anemia/bleeding | 6 (6.1%) | 7 (5.1%) | |
| Surgical procedures | | | |
| Right hemicolectomy | 50 (50.5%) | 61 (44.9%) | 0.884 |
| Sigmoid resection | 15 (15.2%) | 23 (16.9%) | |
| Colectomy | 14 (14.1%) | 15 (11.0%) | |
| Left hemicolectomy | 10 (10.1%) | 20 (14.7%) | |
| Hartmann's resection | 7 (7.1%) | 12 (8.8%) | |
| Transverse colon resection | 2 (2.0%) | 4 (2.9%) | |
| High anterior resection | 1 (1.0%) | 1 (0.7%) | |
| Nighttime surgery | 21 (21.2%) | 38 (27.9%) | 0.287 |
| Lymph node yield | 27 (21–38) | 26 (20–36) | 0.663 |
| Lymph node yield >12 | 95 (96.0%) | 131 (96.3%) | 0.987 |
| R1 resection | 6 (6.1%) | 2 (1.5%) | 0.055 |
| Tumor stage | | | |
| I | 2 (2.0%) | 0 (0%) | 0.405 |
| II | 38 (38.4%) | 50 (36.8%) | |
| III | 45 (45.5%) | 66 (48.5%) | |
| IV | 14 (14.1%) | 20 (14.7%) | |
| Adjuvant chemotherapy | 43 (46.7%) | 48 (39.3%) | 0.329 |

Continuous variables are presented as medians and 25th to 75th percentiles and categorical data are presented as numbers (%). ASA: American Society of Anesthesiologist.

by CS in elective settings cannot be directly extrapolated to emergent procedures. Elective colon cancer surgery is always preceded by thorough assessments of the patient's condition and comorbidity, and treatment decisions are made at MDT meetings. Consequently, elective resections are typically well planned and performed on physiologically stable patients, often in a stress-free environment where unexpected adverse events are rare. This is in sharp contrast to the surgical challange to perform emergent resections in which the surgeon have to confront the additional challenge, to manage acute surgical problems in patients who are in a deranged physiological state due to mechanical obstruction or intestinal perforation. The magnitude of this challenge may often be substantial, as a variety of time-critical, high-pressured and occasionally unfamiliar situations require decisions in difficult clinical settings. This implies that the surgical challange to manage patients with acute complications of colon cancer is greater than that of corresponding elective situations.

Although surgical specialization implies expertise in a specific area of surgery, specialization alone does not imply surgical competence such as technical proficiency, good clinical judgment, or extensive surgical experience. Specialized CSs generally have substantial experience in performing adequate oncologic surgery for colon cancer, but may lack experience in

**Table 2.** Patient characteristics and descriptions of surgical procedures in patients who underwent emergent colon cancer resections performed by colorectal surgeons, acute care surgeons, and general surgeons.

| | Resections performed by | | | *p*-value |
|---|---|---|---|---|
| | Colorectal surgeons, *n* = 99 | Acute care surgeons, *n* = 107 | General surgeons, *n* = 29 | |
| Age (years) | 76 (68–83) | 77 (66–84) | 81 (72–86) | 0.165 |
| Gender (female/male) | 47:52 | 53:54 | 13:16 | 0.892 |
| ASA classification | | | | |
| I | 10 (10.1%) | 16 (15.0%) | 2 (6.9%) | 0.348 |
| II | 43 (43.4%) | 48 (44.9%) | 10 (34.5%) | |
| III | 41 (41.4%) | 38 (35.5%) | 17 (58.6%) | |
| IV | 5 (5.1%) | 5 (4.7%) | 0 (0.0%) | |
| Indications for surgery | | | | |
| Obstruction | 81 (81.8%) | 89 (83.2%) | 24 (82.8%) | 0.592 |
| Perforation | 12 (12.1%) | 11 (10.3%) | 5 (17.2%) | |
| Anemia/bleeding | 6 (6.1%) | 7 (6.5%) | 0 (0%) | |
| Surgical procedures | | | | |
| Right hemicolectomy | 50 (50.5%) | 48 (44.9%) | 13 (44.8%) | 0.392 |
| Sigmoid resection | 15 (15.2%) | 21 (19.6%) | 2 (6.9%) | |
| Colectomy | 14 (14.1%) | 9 (8.4%) | 6 (20.7%) | |
| Left hemicolectomy | 10 (10.1%) | 18 (16.8%) | 2 (6.9%) | |
| Hartmann's resection | 7 (7.1%) | 7 (6.5%) | 5 (17.2%) | |
| Transverse colon resection | 2 (2.0%) | 3 (2.8%) | 1 (3.4%) | |
| Low anterior resection | 1 (1.0%) | 1 (0.9%) | 0 (0%) | |
| Nighttime surgery | 21 (21.2%) | 26 (24.3%) | 9 (31.0%) | 0.544 |
| Lymph node yield | 27 (21–38) | 26 (20–36) | 28 (21–40) | 0.663 |
| Lymph node yield >12 | 95 (96.0%) | 103 (96.3%) | 28 (96.6%) | 0.987 |
| R1 resection | 6 (6.1%) | 1 (0.9%) | 1 (3.4%) | 0.128 |
| Tumor stage | | | | |
| I | 2 (2.0%) | 0 (0%) | 0 (0%) | 0.601 |
| II | 38 (38.4%) | 42 (39.3%) | 8 (27.6%) | |
| III | 45 (45.5%) | 49 (45.8%) | 17 (58.6%) | |
| IV | 14 (14.1%) | 16 (15.0%) | 4 (13.8%) | |
| Adjuvant chemotherapy | 43 (46.7%) | 40 (41.2%) | 8 (32.0%) | 0.393 |

Continuous variables are presented as medians and 25th to 75th percentiles and categorical data are presented as numbers (%). ASA: American Society of Anesthesiologist.

managing acute surgical problems in critically ill patients. Conversely, ACSs may have extensive experience in managing acute surgical problems in critically ill patients, but may have less experience in performing comprehensive oncological dissections. Given the complex nature of emergent surgery for colon cancer, it is not immediately obvious which type of surgical specialization is best suited for these procedures.

Although there are some reports suggesting that specialized CSs have better short-term outcomes following emergent resections for colon cancer,[16] there are numerous studies reporting similar morbidity and mortality rates in patients who underwent emergent colon resections performed by CS and NCS.[17–22] In contrast to the relative abundance of studies of the effect of surgical specialization on short-term results, it is problematic that similar reports on long-term survival outcomes are lacking. To our knowledge, the only available report on long-term outcomes following emergent resections for colon cancer performed by surgeons with different specializations is a retrospective study based on data from the SCRCR, which included 2931 emergent resections performed in Sweden between 2007 and 2010.[2] In contrast to the findings in the present study, Bergvall et al. reported an odds ratio for 5-year mortality in patients operated by NCS that was more than two times higher than that of patients operated on by CS, concluding that long-term survival was superior for patients operated by CS.

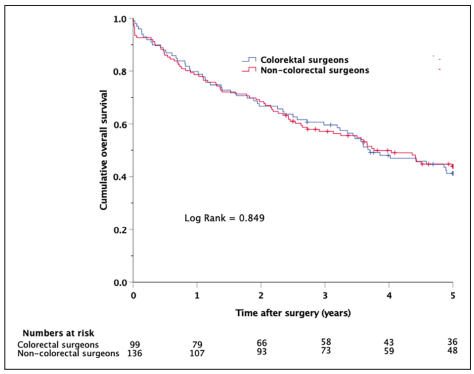


**Fig. 1.** Kaplan–Meier plot showing cumulative overall survival in patients who underwent emergent colon cancer resections performed by colorectal and non-colorectal surgeons.

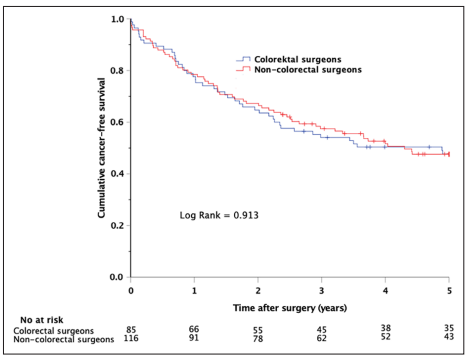


**Fig. 2.** Kaplan–Meier plot showing cumulative cancer-free survival in patients who underwent emergent colon cancer resections performed by colorectal and non-colorectal surgeons.

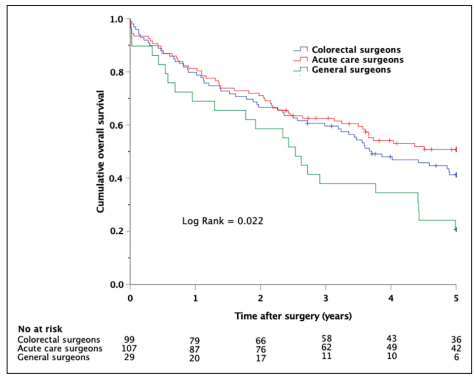


**Fig. 3.** Kaplan–Meier plot showing cumulative overall survival in patients who underwent emergent colon cancer resections performed by colorectal surgeons, acute care surgeons, and general surgeons.

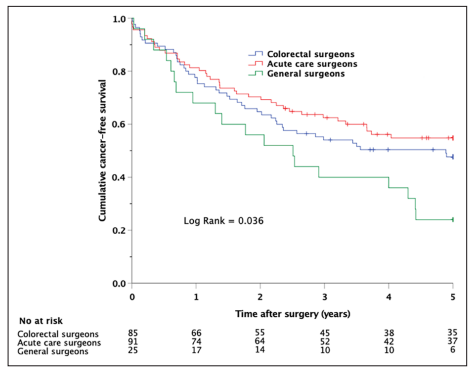


**Fig. 4.** Kaplan–Meier plot showing cumulative cancer-free survival in patients who underwent emergent colon cancer resections performed by colorectal surgeons, acute care surgeons, and general surgeons.

The contrasting conclusions between the present study and that of Bergvall et al. may be attributed to differences in the definitions of emergent surgery and the relative importance of the participation of surgeons with an interest in colorectal surgery. In the present study, emergent surgery was defined as resections performed within 48 h of admission. In contrast, in studies solely based on data from the SCRCR, emergent surgery is defined as procedures conducted during an unplanned admission due to acute medical conditions, regardless of the time from admission.[27] This broader definition of emergent surgery is problematic because it leads to more heterogenous groups of patients that are difficult to compare as they require surgery at different times from admission depending on the severity of their conditions. The most critically ill patients willrequire immediate surgery, even during nighttime, when CS may not be available at many surgical units. Furthermore, the less critically ill patient can often wait until the following morning or even longer. Thus, it is possible that a definition of emergent surgery with no time limit leads to to a selection of less critically ill patients being operated on by CS several days after admission, which may lead to more favorable postoperative outcomes compared with those of surgeons with other specializations.

Although there was no significant difference in the proportion of resections performed by CS and NCS during nighttime in the present study, this perception is supported by a study from a tertiary center in Norway. They reported that only 7% of emergent colorectal cancer resections were performed by specialized gastrointestinal surgeons at night, which was

significantly lower than the proportion of emergent resections performed by this group of during daytime.[28] Another potential reason for the contrasting conclusions of the studies is the relative importance of the involvment of of surgeons with an interest in colorectal surgery. Studies solely based on data from the SCRCR only have information on the highest formal competence in colorectal surgery but lacks information regarding the competence of other surgeons actively involved in the procedures. In Sweden, and most likely in many other countries, emergent resections for colon cancer are rarely performed by a single surgeon alone. It is therefore not uncommon that a relatively inexperienced surgeon with an interest in colorectal surgery performs emergent colon resections in collaboration with a more experienced non-colorectal surgeon. There was a marked difference in the proportion of emergent resections performed by CS in the study by Bergvall et al. and the present study (68% vs. 42%). This discrepancy may be due todifferences in the emphasis placed on the involvement of surgeons with an interest in colorectal surgery.

In the study by Bergvall et al., CSs were registered as the highest surgical competence, regardless of the experience and competence of other surgeons involved in the procedures, whereas we defined seniority and responsibility based on surgical experience alone. It is possible that Bergvall and coworkers registered resections as being performed by CS although they were performed in collaboration with more experienced surgeons with other specializations, a procedure for wich the latter rather than the former, has the overall responsibility for the quality and outcome. Consequently, the contrasting results and conclusions of the two studies may be explained by differences in the definitions of emergent surgery in combination with differences concerning the significance placed on the participation of CS, regardless of the surgical experience of other surgeons involved in the procedure.

The observation that the tumor stage, the lymph node yield, the rate of R0 resections and the OS and CFS were similar in patients operated on by CS and ACS suggests that the oncological quality of resections for colon cancer performed by these groups of surgeons was equivalent. However, the less favorable long-term survival observed in patients operated on by GS is more difficult to explain as tumor characteristics and lymph node yield were comparable with those of patients operated on by CS and ACS. In a previous study based on the same study population, patients who underwent emergent colon resections performed by GS had significantly more frequent and severe postoperative complications.[17] Given that complications are associated with poor long-term survival,[7,29,30] one can speculate as to whether the observed differences in long-term survival could be explained by a higher complication rate in patients operated by GS. However, as the group of patients operated on by GS was relatively small, conclusions should be made with caution.

A key strength of this study is the homogeneity of the study population, with no patients having rectal cancer or benign disease. The clear definition of emergent surgery only including resections performed within 48 h of admission, as well as the identification of the specialization of the most senior surgeon actively involved in the procedures, also adds to the study's robustness. Limitations of the study include its retrospective nature, which may limit precision and validity compared with prospective trials, although conducting a prospective randomized trial in this setting would be extremely challenging. Another limitation is the single center cohort design that may limit generalizability, as local variations in patient selection and surgical practice may influence outcomes. Furthermore, as the definition of surgical specializations may vary between studies, conclusions may not be universal, and comparisons should be made with caution.

In conclusion, the findings of this study suggest that emergent resections for colon cancer were performed with equivalent oncological quality by CS and NCS, and the subgroup consisting of ACS. This was suggested by similar numbers of harvested lymph nodes , similar R0 resection rates, and similar OS and CFS. However, patients operated on by GS had less favorable long-term survival, possibly due to less frequent exposure to both colorectal and emergent surgery. Regular rotations at acute care and colorectal units to preserve competence and maintain surgical quality may be needed to improve long-term outcomes for patients requiring emergent colon cancer resections.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Research ethics and patient consent

The study was approved by the Swedish Ethical Review Authority (2019-04329) and according to the approval informed consent was not needed.

## Clinical trial registration

Not applicable.

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# Paper III

*Original Article*

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# Short- and long-term outcome after colon cancer resections performed by male and female surgeons: A single-center retrospective cohort study

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**Abstract**

**Background and objective:** To assess the effect of surgeon sex on short- and long-term outcomes after colon cancer resections.

**Methods:** Clinical data of patients who underwent colon cancer resections between 2010 and 2020 at Helsingborg Hospital, Sweden, were retrospectively obtained from medical records. The sex of the surgeon of each procedure was recorded. Morbidity, mortality, and long-term survival were compared in patients operated by male and female surgeons.

**Results:** Colon cancer resections were performed by 23 male and 9 female surgeons in 1113 patients (79% elective, 21% emergent). After elective surgery, there was no difference in postoperative complications, 30-day mortality, or long-term survival between patients operated by male and female surgeons. Following emergent resections, the complication rate was significantly lower in patients operated by female surgeons (41.3% vs 58.1%, p = 0.019). Similarly, the rates of R1-resections (0% vs 5.2%, p = 0.039), reoperations (3.8% vs 14.2%, p = 0.014), and intensive care unit (ICU) care (6.3% vs 17.4%, p = 0.018) were significantly lower for patients operated by female surgeons, but there was no difference in 30-day mortality (6.3% vs 5.2%, p = 0.767). Cox regression analysis showed that long-term and cancer-free survival in patients emergently operated by male surgeons was significantly shorter than that of patients operated by female surgeons (hazard ratio = 1.9 (95% confidence interval (CI) = 1.3–2.8), p = 0.001 and hazard ratio = 1.7 (95% CI = 1.1–2.7), p = 0.016).

**Conclusions:** The short- and long-term outcome after elective colon cancer resections were similar in patients operated by male and female surgeons. The outcome following emergent resections performed by female surgeons compared favorably with that of male surgeons, with fewer complications and reoperations and better long-term survival.

**Keywords**

Surgeon sex, short-term outcomes, long-term outcomes, elective colon resection, emergency colon resection, colon cancer

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## Context and Relevance

It is generally accepted that there are variations in surgical outcomes, and these are often attributed to patient-related factors, although there is increasing evidence to suggest that also surgeon-related factors affect postoperative outcomes.

As information regarding the effect of surgeon sex on postoperative outcome is limited, we retrospectively studied the short- and long-term results after colon cancer resections performed by male and female surgeons at a secondary care hospital. Elective resections were performed with similar quality by male and female surgeons, with comparable oncological quality, similar rates of complications and mortality, and similar long-term survival. Following emergent colon cancer resections, patients operated by female surgeons had fewer and less severe postoperative complications and better long-term survival.

## Introduction

It is generally accepted that there are variations in surgical outcomes, and these are often attributed to patient-related factors such as age, comorbidities, or the severity of underlying disease. However, there is increasing evidence to suggest that also surgeon-related factors are associated with quality and postoperative outcome.[1] Although surgery is a craft specialty, technical proficiency is not the only surgeon-related determinant for a good postoperative outcome, and adequate knowledge, communication skills, and clinical judgment may be equally important for patient outcome.[2,3] Thus, clinical experience and individual personality including surgeon attitudes and risk propensity, and the ability to facilitate teamwork may also be factors that influence patient outcome.[4]

In the field of internal medicine, there are several studies reporting that male and female physicians practice medicine differently.[5–11] These studies conclude that female physicians are more prone to use and follow guidelines, have more effective communication, and provide a more patient-centered care resulting in better quality of care and lower rates of mortality and readmissions compared with their male counterparts.[6,11]

Our interest in the potential effects of surgeon sex on postoperative outcome was stimulated by the report of Wallis et al.[3] who compared outcomes of male and female surgeons in over 100,000 patients after a wide range of different operations across many surgical specialties. They concluded that there was a small statistically significant difference in 30-day mortality in favor for patients operated by female surgeons, but no differences in the rates of complications or readmissions. In a similar study, Sharoky and coworkers reported short-term outcome after 44 different general surgery operations with a wide range of complexity. They concluded that patients operated by male and female surgeons had equivalent rates of inpatient mortality, postoperative complications, and prolonged length of hospital stay.[12] Similar short-term outcome in patients operated by male and female surgeons was also reported in a recent cohort study including patients who underwent elective distal gastrectomy, total gastrectomy, or low anterior resections performed by surgeons who were members of the Japanese Society of Gastroenterological Surgery.[13] Information regarding the effect of surgeon sex on postoperative outcome is limited, and available studies are inconclusive and based on a wide range of different surgical procedures with varying complexity.[3,12]

We therefore aimed to assess whether surgeon sex had an effect on the surgical outcomes in a more homogeneous cohort of patients undergoing a single, but more complex surgical procedure. The aim of this retrospective observational study was to evaluate the effect of surgeon sex on postoperative morbidity, mortality, and long-term survival following colon cancer resection in a secondary care hospital cohort.

## Methods

### Study population

All patients who underwent elective and emergent resections for colon cancer between 2010 and 2020 at Helsingborg Hospital, Sweden, were identified from the Swedish Colorectal Cancer Registry (SCRCR). The SCRCR is a validated national registry with a coverage of 98.5% of all colon cancers in Sweden.[14] Helsingborg Hospital is a secondary care hospital with a catchment area of 350,000 residents. Patients younger than 18 years of age, patients who underwent colon resections for benign disease, and patients with rectal or appendix cancer were not included. Unplanned colon resections performed within 48 h after acute admission were defined as emergency operations, and all other resections were defined as elective procedures. No patients with a need for elective or emergency colon resections were referred to other hospitals, and the postoperative care was provided at the colorectal surgery unit. The use of stents as a bridge to elective surgery in patients with obstructing colon cancers was not practiced during the study period.

The sex of the most senior surgeon actively participating in each of the colon resections was recorded. The yearly median number of all colon resections (elective and emergency procedures) for cancer in which the surgeons had actively participated was calculated. Colon resections for benign disease and rectal cancer were not included in this annual number. The overall surgical experience, defined by the date from surgical board certification to the date of surgery, was calculated for the surgeons of all resections. Night surgery was defined as a surgical incision time between 17:00 and 07:00 h.

Demographic, clinical data, and tumor characteristics of the patients were obtained from the SCRCR. To obtain additional data and to validate the information from the registry, three researchers conducted a retrospective review of the

medical records. A guideline for retrospective medical record reviews was followed to reduce the risk of information bias during data collection.[15] The Charlson Comorbidity Index (CCI) was used to classify the comorbidity burden of the patients,[16] and the stage of colon cancer was categorized from I to IV.[17] Patients in whom all visible tumors were not removed during the procedures were defined as having macroscopically generalized cancer. The Clavien–Dindo classification (grades II to IV) was used to characterize the nature and severity of complications.[18] Preoperative treatment decisions were made at a multidisciplinary tumor board (MDT) in all patients undergoing elective resections. Decisions regarding adjuvant treatment were made postoperatively at MDT for all patients.

The primary outcomes of interest were the occurrence and the severity of complications, the need for intensive care unit (ICU) care, reoperations, and the 30- and 90-day mortality rates in patients operated by male and female surgeons. The long-term overall- and cancer-free survival was assessed and compared in the same groups of patients as secondary aims.

### Statistical analysis

As continuous data were not normally distributed results were reported as medians and 25th–75th percentiles, and comparisons were made using non-parametric statistics. The Mann–Whitney *U*-test was used to compare continuous data between two groups. Proportions were analyzed using the chi-square test. Binary logistic regression analyses were used to evaluate associations between multiple factors on binary outcomes, and variables considered clinically important were entered simultaneously for adjustments in the regression models. The factors adjusted for in patients having elective resections included patient sex, the American Society of Anesthesiologists (ASA) classification, pathological tumor stage, annual resection volume, overall surgical experience, and the surgical approach. For emergent resections, adjustments were made for the same factors with the addition of nighttime surgery and indication for emergent surgery. From the day of surgery, the cumulative overall survival was plotted using the Kaplan–Meier method, counting deaths as events and the remainder as censored as of the last day of follow-up. Similarly, cancer-free survival was plotted counting deaths or cancer recurrence as events and the rest as censored. Comparisons of cumulative survival between groups were made using the log rank test. Cox regression analysis was performed to assess the effect of multiple variables and to adjust for potentially confounding factors on overall- and cancer-free survival. For elective resections, adjustments in the Cox models were made for patient sex, patient age, ASA classification, tumor stage, annual resection volume, overall surgical experience, and surgical approach. Adjustments for emergent resection were made for the same factors with addition of nighttime surgery and indication for emergent resections. A $p < 0.05$ was considered statistically significant.

All statistical analyses were performed using the IBM SPSS® Statistics ver. 25 (IBM Corp., Armonk, NY, USA). The study was approved by the Swedish Ethical Review Authority (2019-04329).

## Results

During the study period, 1113 patients underwent resection for colon cancer at Helsingborg Hospital. Eight-hundred and seventy-eight (79%) of these patients underwent elective resections and 235 (21%) emergency resections. All colon resections were performed by board certified general surgeons. Elective colon resections were performed by 10 male and 9 female surgeons with similar median annual resection volumes (11.8 (7.2–23.9) vs 18.7 (7.8–28.0) resections per year, $p = 0.762$). There was no significant difference in the resection volumes between 23 male and 8 female surgeons performing the emergency procedures (11.0 (6.5–24.9) vs 6.0 (1.6–18.2), $p = 0.122$). Eight of the female surgeons who performed elective resections also performed emergent resections and 10 male surgeons performed both elective and emergent resection whereas 13 male surgeons performed emergent resections only. There was no significant difference in the overall surgical experience of male and female surgeons performing elective and/or emergent resections (12.3 (7.6–19.7) vs 16.3 (9.2–21.3), $p = 0.712$ and 16.3 (9.6–21.7) vs 19.3 (6.2–21.3), $p = 0.122$, respectively).

In patients who underwent elective resections, female surgeons operated a statistically significantly larger proportion of female patients, but no such difference was observed in patients who underwent emergency resection (Table 1). The distribution of emergency resection due to mechanical obstruction, perforation, or anemia/bleeding was similar in patients operated by male and female surgeons (80.0% vs 87.5%, 12.9% vs 12.0%, and 7.1% vs 2.5%, respectively, $p = 0.253$). There was no difference in the proportion of emergent colon resections performed during nighttime between male and female surgeons (24.5% vs 22.5%, $p = 0.731$).

There was no statistically significant difference in the distribution of the types of resections performed by male and female surgeons, but the proportion of elective laparoscopic resections was statistically significantly higher in patients operated by male surgeons (Table 2). Furthermore, the operating time, the lymph node yield, and the tumor stage were similar regardless of surgeon sex. After emergency colon resection, the rate of R0-resections was statistically significantly higher in patients operated by female surgeons, but no such difference was seen in patients who underwent elective resections.

The proportion and the severity of complications following elective colon resection were similar in patients operated by female and male surgeons. Following emergency resection, the overall complication rate and the rate of complication Clavien–Dindo III or greater were statistically

**Table 1.** Clinical characteristics of patients who underwent elective and emergent colon cancer resections performed by female and male surgeons.

| | Elective surgery | | | Emergent surgery | | |
|---|---|---|---|---|---|---|
| | Female surgeons (n = 178) | Male surgeons (n = 700) | p | Female surgeons (n = 80) | Male surgeons (n = 155) | p |
| Age (years) | 75 (68–81) | 74 (67–80) | 0.544 | 76 (66–83) | 77 (69–84) | 0.372 |
| Male/female | 70/108 | 342/358 | 0.023 | 37/43 | 85/70 | 0.219 |
| BMI | 26.7 (23.6–29.1) | 25.9 (24.5–29.1) | 0.545 | 23.9 (22.1–27.1) | 24.2 (21.8–27.5) | 0.968 |
| ASA classification | | | | | | |
| I | 22 (12.4%) | 117 (16.7%) | 0.102 | 11 (13.8%) | 17 (11.0%) | 0.742 |
| II | 91 (51.1%) | 389 (55.6%) | | 36 (40.0%) | 65 (41.9%) | |
| III | 62 (34.8%) | 182 (26.0%) | | 29 (36.3%) | 67 (43.2%) | |
| IV | 3 (1.7%) | 12 (1.7%) | | 4 (5.0%) | 6 (3.9%) | |
| Charlson Comorbidity Index | | | | | | |
| 2 | 102 (57.3%) | 423 (60.4%) | 0.995 | 41 (51.2%) | 67 (43.2%) | 0.230 |
| 3 | 46 (25.8%) | 168 (24.0%) | | 14 (17.5%) | 35 (22.6%) | |
| 4 | 18 (10.1%) | 63 (9.0%) | | 7 (8.8%) | 21 (13.5%) | |
| 5 | 3 (1.7%) | 12 (1.7%) | | 2 (2.5%) | 2 (1.3%) | |
| 6 | 6 (3.4%) | 24 (3.4%) | | 10 (12.5%) | 19 (12.3%) | |
| 7 | 2 (1.1%) | 7 (1.0%) | | 2 (2.5%) | 10 (5.8%) | |
| ⩾8 | 1 (0.6%) | 3 (0.4%) | | 4 (5.0%) | 2 (1.2%) | |

BMI: body mass index; ASA: American Society of Anesthesiologist.

significantly lower in patients operated by female surgeons (Table 3). After elective colon resections, the need for care at the ICU, the proportion of reoperations, and unplanned readmissions were similar in patients operated by male and female surgeons. The proportion of 30- and 90-day mortality following elective and emergency colon resection were similar regardless of surgeon sex.

The cumulative survival of patients undergoing elective colon cancer resection was similar in patients operated by female and male surgeons (Figure 1). Following emergency resection, the long-term survival was statistically significantly better in patients operated by female surgeons (Figure 2). In a Cox regression analysis with adjustments for factors perceived as clinically relevant for survival, emergent colon resections performed by male surgeons were associated with a significantly shorter survival (hazard ratio (HR) = 1.9 (95% confidence interval (CI) = 1.3–2.8), p = 0.001).

Of the patients without macroscopically generalized cancer at the time of surgery, there was no surgeon sex-related difference in the cumulative cancer-free survival in patients who underwent elective colon resection (Figure 3). However, patients undergoing emergency resections performed by female surgeons had statistically significantly longer cancer-free survival compared with those operated by their male counterparts (Figure 4). In an additional Cox regression analysis adjusting for clinical factors considered to potentially affect survival, there was a significant association between emergent resections performed by male surgeon and shorter cancer-free survival (HR = 1.7 (95% CI = 1.1–2.7), p = 0.016).

## Discussion

To our knowledge, this represents the first study comparing short- and long-term outcomes of elective and emergency colon cancer resection in patients operated by male and female surgeons. This retrospective observational cohort study found no surgeon sex-related difference in the short- or long-term outcome in patients who underwent elective resection for colon cancer as both male and female surgeons provided comparable oncological quality, similar rates of complications and mortality, and similar long-term survival. However, following emergency colon cancer resection, we observed that patients operated by female surgeons had fewer and less severe postoperative complications, less reoperations, ICU care, and furthermore, better long-term survival and longer cancer-free survival.

The observation that the complication and mortality rates were equally good in patients who underwent elective colon resections performed by male and female surgeons indicates equivalent technical proficiency of male and female surgeons further supported by the similar median number of resected lymph nodes and the proportion of R0-resections. The similarities in the quality of the oncologic technique most likely

**Table 2.** Characteristics of elective and emergent colon cancer resections in patients operated by female and male surgeons.

| | Elective surgery | | | Emergent surgery | | |
|---|---|---|---|---|---|---|
| | **Female surgeons (n = 178)** | **Male surgeons (n = 700)** | **p** | **Female surgeons (n = 80)** | **Male surgeons (n = 155)** | **p** |
| Types of colon resections | | | | | | |
| Right hemicolectomy | 96 (53.9%) | 360 (51.4%) | 0.713 | 35 (43.8%) | 76 (49.8%) | 0.298 |
| Sigmoid resection | 49 (27.5%) | 187 (26.7%) | | 18 (22.5%) | 20 (12.9%) | |
| Left hemicolectomy | 19 (10.7%) | 68 (9.7%) | | 11 (13.8%) | 19 (12.3%) | |
| Anterior resection | 5 (2.8%) | 19 (2.7%) | | 1 (1.3%) | 1 (0.6%) | |
| Colectomy | 4 (2.2%) | 23 (3.3%) | | 9 (11.3%) | 20 (12.9%) | |
| Hartmann resection | 3 (1.7%) | 25 (3.6%) | | 3 (3.8%) | 16 (10.3%) | |
| Transverse colon resection | 2 (1.1%) | 18 (2.6%) | | 3 (3.8%) | 3 (1.9%) | |
| Laparoscopic/robotic resections | 16 (9.0%) | 166 (23.7%) | <0.001 | 0 (0%) | 2 (1.3%) | 0.308 |
| Operating time (min) | 175 (146–224) | 170 (138–216) | 0.167 | 185 (149–258) | 192 (154–230) | 0.719 |
| Bleeding (mL) | 100 (50–163) | 75 (50–150) | 0.007 | 150 (50–200) | 150 (100–300) | 0.572 |
| Lymph node yield | 26 (21–34) | 26 (19–35) | 0.734 | 25 (19–34) | 28 (22–39) | 0.112 |
| <12 lymph nodes | 2 (1.1%) | 24 (3.4%) | 0.137 | 4 (5.0%) | 5 (3.2%) | 0.494 |
| R0-resections | 176 (98.9%) | 687 (98.1%) | 0.500 | 80 (100%) | 147 (94.8%) | 0.039 |
| Stoma formation[a] | 13/77 (16.9%) | 58/311 (18.6%) | 0.720 | 24/46 (52.2%) | 45/82 (54.9%) | 0.768 |
| Macroscopically generalized disease | 12 (6.7%) | 29 (4.1%) | 0.142 | 13 (16.3%) | 21 (13.5%) | 0.577 |
| Tumor stage | | | | | | |
| I | 28 (15.7%) | 143 (20.4%) | 0.344 | 1 (1.3%) | 1 (0.6%) | 0.892 |
| II | 81 (45.5%) | 283 (40.4%) | | 30 (37.5%) | 58 (37.4%) | |
| III | 59 (33.1%) | 245 (35.0%) | | 36 (45.0%) | 75 (48.4%) | |
| IV | 10 (5.6%) | 29 (4.1%) | | 13 (16.3%) | 21 (13.5%) | |

[a]Only patients with left-sided cancers included in the analysis.

explain the observation that the long-term and cancer-free survival was similar in elective patients, regardless of the sex of the surgeon.

The observation that the postoperative outcome was equivalent in patients undergoing elective colon resections performed by male and female surgeons, but differed significantly following emergent surgery is intriguing. Every elective case is preceded by assessments of the patient's condition and comorbidity, and the treatment decisions are made at MDT. Consequently, elective colon resections are well-planned and performed on physiologically stable patients, often in a stress-free environment where unplanned adverse events are rare. This is in contrast to the surgical challenge to perform emergent resections as the surgeon has to face the additional challenge in managing acute surgical problems in patients who are often in a poor physiologic condition due to perforation or mechanical obstruction. The magnitude of this challenge may often be substantial as a variety of time-critical, high-pressured, and occasionally unfamiliar situations require decisions in clinically difficult circumstances, that is, the surgical challenge during emergency resection is greater compared to corresponding elective situation.

The observed differences in the rates of complications, reoperations, and ICU care after emergent resections performed by male and female surgeons are interesting, but a causal relation is, difficult to prove. The differences in postoperative results could potentially be explained by patient-related factors and that more complicated cases was operated by male surgeons. However, patient-related factors such as age, ASA classification, CCI, tumor stage, and the distribution of perforation and mechanical obstruction were similar in patients operated by male and female surgeons. This observation suggest that the complexity of the procedures was equivalent in patients operated by male and female surgeons, and the adjustments for these factors in our regression models did not change the observation that the sex of the surgeons had a significant influence on postoperative outcomes.

Apart from patient-related factors, the observed differences in postoperative outcome following emergency colon

**Table 3.** Postoperative complications and outcome after elective and emergent colon cancer resections in patients operated by female and male surgeons.

| | Elective surgery | | | Emergent surgery | | |
|---|---|---|---|---|---|---|
| | Female surgeons (n=178) | Male surgeons (n=700) | p | Female surgeons (n=80) | Male surgeons (n=155) | p |
| Clavien–Dindo classification of complications | | | | | | |
| No complication | 114 (64.0%) | 467 (66.7%) | 0.945 | 47 (58.8%) | 64 (41.3%) | 0.034 |
| Clavien–Dindo II | 52 (29.2%) | 183 (26.1%) | | 22 (27.5%) | 48 (31.0%) | |
| Clavien–Dindo III | 8 (4.5%) | 32 (4.6%) | | 1 (1.3%) | 16 (7.1%) | |
| Clavien–Dindo IV | 2 (1.1%) | 10 (1.4%) | | 5 (6.3%) | 23 (14.8%) | |
| Clavien–Dindo V | 2 (1.1%) | 8 (1.1%) | | 5 (6.3%) | 9 (5.8%) | |
| Any complication | 64 (36.0%) | 233 (33.3%) | 0.535 | 33 (41.3%) | 91 (58.7%) | 0.011 |
| Binary regression | Reference | 1.0 (0.7–1.5)[a] | 0.991 | Reference | 2.4 (1.3–4.6)[b] | 0.006 |
| Clavien–Dindo > II | 12 (6.7%) | 50 (7.1%) | 1.000 | 11 (13.8%) | 43 (27.7%) | 0.016 |
| Binary regression | Reference | 1.5 (0.7–3.1)[a] | 0.326 | Reference | 2.8 (1.3–6.2)[b] | 0.008 |
| Hospital stay (days) | 9 (7–13) | 8 (6–12) | 0.002 | 12 (9–17) | 13 (8–24) | 0.228 |
| Reoperations | 10 (5.6%) | 31 (4.4%) | 0.550 | 3 (3.8%) | 22 (14.2%) | 0.014 |
| Binary regression | Reference | 1.1 (0.5–3.1)[a] | 0.326 | Reference | 4.9 (1.3–18.2)[b] | 0.017 |
| ICU care | 7 (3.9%) | 19 (2.7%) | 0.455 | 5 (6.3%) | 27 (17.4%) | 0.018 |
| Binary regression | Reference | 1.2 (0.4–3.6)[a] | 0.706 | Reference | 3.1 (1.1–8.8)[b] | 0.035 |
| 30-day mortality | 0 (0%) | 8 (1.1%) | 0.370 | 5 (6.3%) | 8 (5.2%) | 0.767 |
| 90-day mortality | 3 (1.7%) | 11 (1.6%) | 1.000 | 5 (6.3%) | 13 (8.4%) | 0.617 |
| Readmissions[c] | 14/176 (8.0%) | 51/692 (7.4%) | 0.750 | 5/75 (6.7%) | 17/146 (11.6%) | 0.343 |
| Adjuvant chemotherapy[d] | 43/162 (26.5%) | 193/658 (29.3%) | 0.500 | 25/63 (39.7%) | 50/126 (39.7%) | 1.000 |

Continuous variables expressed as medians and 25th–75th percentiles and categorical variables as numbers (%).
[a]Binary logistic regression analysis with adjustments for patient sex, ASA classification, tumor stage, the annual surgeon resection volume, overall surgical experience, and the surgical approach. Expressed as odds ratio (95% confidence interval).
[b]Binary logistic regression analysis with adjustments for ASA classification, the annual surgeon resection volume, overall surgical experience, tumor stage, night surgery, and indication for emergent surgery. Expressed as odds ratio (95% confidence interval).
[c]Patients with in-hospital mortality were excluded from the analysis.
[d]Patients with generalized disease at the time of surgery and patients with in-hospital mortality were excluded from the analysis.

**Emergent surgery.**

| | Female | Male | p |
|---|---|---|---|
| Any complication—binary regression | Reference | ( - )‡ | 0. |
| Clavien–Dindo > II—binary regression | Reference | ( - )‡ | 0. |
| Reoperations—binary regression | Reference | ( - )‡ | 0. |
| ICU-care—binary regression | Reference | 3.3 (1.1- ))‡ | 0. |
| Overall survival—Cox regression | Reference | 3.3 (1.1- ))‡ | 0. |
| Cancer-free survival—Cox regression | | 3.3 (1.1- ))‡ | 0. |

Variables Binary regression:
Variables Cox regression:

**Elective surgery.**

| | Female | Male | p |
|---|---|---|---|
| Any complication—binary regression | Reference | ( - ))‡ | 0. |
| Clavien-Dindo > II—binary regression | Reference | ( - ))‡ | 0. |
| Reoperations—binary regression | Reference | ( - ))‡ | 0. |
| ICU-care—binary regression | Reference | 3.3 (1.1- ))‡ | 0. |
| Overall survival—Cox regression | Reference | 3.3 (1.1- ))‡ | 0. |
| Cancer-free survival—Cox regression | | 3.3 (1.1- ))‡ | 0. |

Variables Binary regression:
Variables Cox regression:

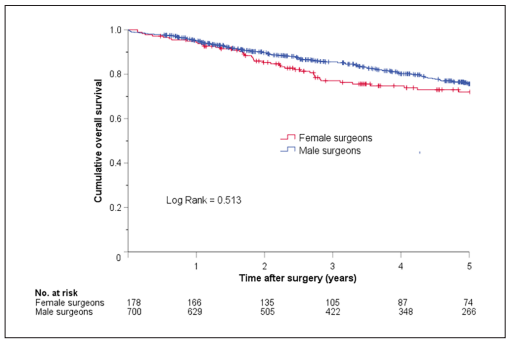


**Figure 1.** Kaplan–Meier plot showing cumulative overall survival in patients who underwent elective colon cancer resections performed by female and male surgeons.

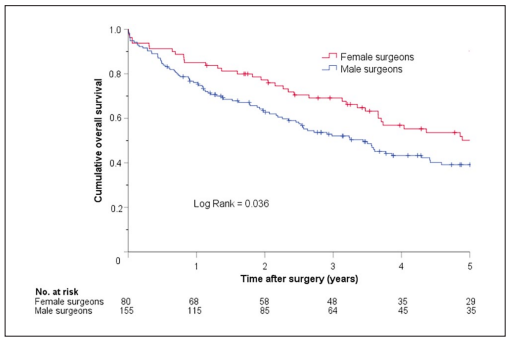


**Figure 2.** Kaplan–Meier plot showing cumulative overall survival in patients who underwent emergent colon cancer resections performed by female and male surgeons.

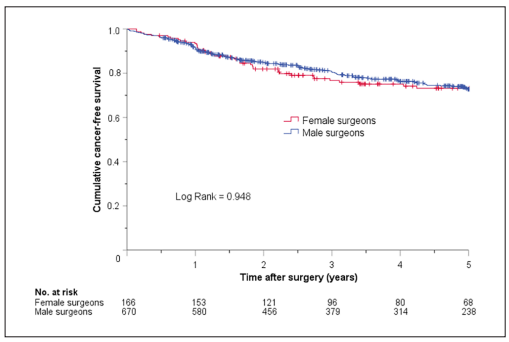


**Figure 3.** Kaplan–Meier plot showing cumulative cancer-free survival in patients who underwent elective colon cancer resections performed by female and male surgeons.

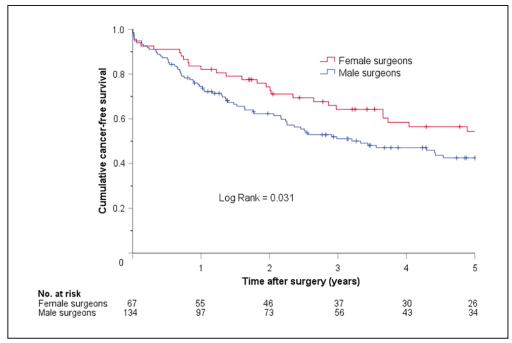


**Figure 4.** Kaplan–Meier plot showing cumulative cancer-free survival in patients who underwent emergent colon cancer resections performed by female and male surgeons.

resection may potentially be explained by factors related to the surgeons. Surgical specialization may potentially affect outcomes, although conclusions in available reports are controversial with several studies reporting similar outcomes after emergent colon resections performed by specialized colorectal and non-colorectal surgeons.[19–25] As colorectal surgeons generally have higher annual resection volumes than non-colorectal surgeons, we used resection volumes as a proxy for surgical specialization in the regression models, but these adjustments did not change the effect of the surgeon sex on the outcomes. The observation that the outcome following emergent colon resections was better in patients operated by female surgeons, regardless of surgical specialization, was further strengthened in an additional sensitivity analysis including only patients operated by the 10 male and the 8 female surgeons who performed both elective and emergent colon resections. Although we made adjustments for median annual resection volumes in our regression models, the numerical but non-significant difference in resection volumes in emergent resections performed by male and female surgeons raises a concern for a volume effect on the outcome. To address this concern, we made a sensitivity analysis by excluding all patients who had emergent resections performed by surgeons with an annual resections volume lower than 5 per year. Although the number of patients included in the analyses was somewhat lower, the significant difference regarding overall and severe complications, reoperations, and ICU care in favor of patients operated by female surgeons remained. This observation reduces the likelihood of a volume effect and strengthens the suggestion that there was a true difference in outcome following emergent colon resections performed by male and female surgeons.

The observed differences in long-term and the cancer-free survival after emergent resections in favor for patients operated by female surgeons is interesting but difficult to explain as patient characteristics and tumor stages were similar in

patients operated by male and female surgeons. Although patients operated by female surgeons had a significantly higher proportion of R0-resections, a casual association is difficult to prove and the reasons for the observed survival advantages remains unknown. As patients operated by female surgeons had a significantly lower proportion of complications, and the occurrence of complications has been shown to correlate with poor long-term survival,[26,27] one can speculate as to whether the observed difference in long-term survival could partially be explained by the corresponding difference in the rate of complications.

Studies suggesting that male and female physicians practice medicine different than their male counterparts may possibly explain the observed differences in postoperative outcomes following emergency colon resection. Female physicians have been shown to possess superior communication skills[5–11] and successful surgery depends on effective teamwork involving collaboration, coordination, and communication both in the operating room and on the surgical ward.[28–29] It has also been shown that female physicians adhere more closely to evidence-based guidelines and provide more patient-centered care, which are characteristics that may be favorable for patients in need of emergency surgery.[5–11] Furthermore, it has been shown that female physicians are more risk averse than their male counterparts,[5–11] which may affect the selection of patients for surgery and/or the decision whether to perform resections or not. Hypothetically, these traits, which in general appear to characterize female physicians, may make them better suited for management of patients in emergent situations. This assumption is supported by a study that showed that patients with cardiac arrest treated by female physician code leaders had a higher adjusted likelihood of return to spontaneous circulation and survival.[29]

The major limitation of this study is the retrospective observational nature of this study as retrospective studies generally are inferior to prospective trials regarding precision and validity. Another limitation is the single-center cohort study design as local variations within the group of surgeons and the surgical teams, or possible differences in indications for surgery may decrease the generalizability of these results. However, the homogeneous cohort of patients undergoing a single, but a more complex surgical procedure with a relatively high rate of complications is a clear strength of our study. Furthermore, the use of administrative data allows the comprehensive identification of readmissions and complications occurring anywhere else in the whole province.

In conclusion, the short- and long-term outcome after elective colon cancer resections was similar in patients operated by male and female surgeons. The outcome following emergent resections performed by female surgeons compared favorably with that of male surgeons, with fewer complications and reoperations, and better long-term survival. These observations need to be confirmed in future studies and the potential underlying mechanisms must be explored as they offer the potential to improve surgical care.

## Author contributions

A.Ö. participated in the acquisition of data and data analysis. J.E. participated in research design, the acquisition of data, the data analysis, and in the writing of the manuscript. S.B.-L. participated in the acquisition of data and in the writing of the manuscript. H.B. participated in critical review of the manuscript. T.V. participated in critical review of the manuscript. M.E. participated in critical review of the manuscript. S.Ö. participated in research design, the acquisition of data, the data analysis, and in the writing of the manuscript.

## Declaration of conflicting interests

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## Research ethics and patient consent

The study was approved by the Swedish Ethical Review Authority (2019-04329), and according to the approval, informed consent was not needed.

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# Paper IV

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**JENNY ENGDAHL** is a colorectal surgeon at Helsingborgs hospital, Sweden. This thesis addresses surgeon related factors effect on patients postoperative outcome after colon cancer surgery.

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