

Incidence and Risk Factors of Post-Colonoscopy Infections in Liver Transplant Candidates: A Retrospective Cohort Study

V. Vandebroek¹, I. Demedts^{1,2}, W. Laleman¹, J. Sabino^{1,2}, S. van der Merwe^{1,2}, J. Verbeek^{1,2}, H. van Malenstein^{1,2}

(1) Department of Gastroenterology and Hepatology, University Hospital Leuven, KU Leuven, Belgium; (2) Department of Chronic Diseases, Metabolism and Aging, KU Leuven, Leuven, Belgium.

Abstract

Background and study aims: Liver transplant candidates, especially those with cirrhosis are more prone to infections, potentially precipitated by semi-invasive procedures like colonoscopy. Limited data exist on infection rates post-colonoscopy and risk factors in this population. We aimed to estimate the incidence of post-colonoscopy infections and explore potential associated risk factors in patients awaiting liver transplantation.

Patients and methods: This retrospective Belgian single-centre cohort study included 141 adult liver transplant candidates undergoing screening colonoscopy (2019-2023) with ≥ 24 h post-procedural observation. Infection was defined as fever $\geq 38^\circ\text{C}$, leucocytosis ($>12,000/\mu\text{L}$), need for antibiotics, or bacteraemia within 72 hours. Demographic, clinical (MELD, Child-Pugh), and procedural variables were analysed. Variables with $p < 0.10$ in univariate analysis were entered into a backward stepwise multivariable logistic regression model for hypothesis generation.

Results: The overall post-colonoscopy infection rate was 6.4% (9/141), increasing to 8.9% (9/101) among cirrhotic patients. Infections included bacteraemia, spontaneous bacterial peritonitis, and pneumonia. Univariate analysis linked higher Child-Pugh score and INR, ascites grade ≥ 2 , and diverticulosis with infection. Multivariable analysis suggested trends for INR ($p=0.051$) and diverticulosis ($p=0.07$). No associations were found with bowel preparation adequacy, sedation type, polypectomy, or antibiotic/immunosuppressive use.

Conclusions: Liver transplant candidates, particularly those with advanced liver disease and diverticulosis, may have a substantial risk of infection following screening colonoscopy. Because all infectious events occurred in patients with cirrhosis, these preliminary findings highlight the need for larger, prospective studies that target this high risk cirrhotic subgroup to confirm risk factors and inform risk stratified management. (*Acta gastroenterol belg.*, 2026, 89, 457-464).

Keywords: Liver transplantation, cirrhosis, colonoscopy, antibiotics.

Introduction

Colonoscopy is a routine but semi-invasive procedure. Although generally safe, its most serious complications, haemorrhage and perforation, occur in only $\leq 0.3\%$ and $0.3\text{--}0.6\%$ of cases, respectively, among the general population undergoing the procedure (1, 2). However, in patients with cirrhosis, infection represents an additional clinically relevant complication, often associated with increased morbidity and mortality (3). This is particularly relevant in decompensated cirrhotic patients, in whom severe infections can precipitate or exacerbate acute-on-chronic liver failure (ACLF), a syndrome characterized by a markedly elevated risk of mortality (4). There are however few data on

the true prevalence of infection following screening colonoscopy, especially in the vulnerable subpopulation of cirrhotic liver transplant candidates.

It is currently also unclear which factors would be responsible for this increased risk. This could be due to patient-related factors, as individuals with decompensated cirrhosis are inherently more susceptible to infection (5, 6). Alternatively, procedure-related factors such as depth of sedation (deep vs. mild), the performance of a polypectomy, or the method and adequacy of bowel preparation, which has been shown to be inferior in cirrhotic patients compared to healthy controls, may influence the risk of infections. Therefore, the role of prophylactic antibiotics in this vulnerable population remains uncertain, with limited and contradictory evidence from available studies (3, 7).

Given the paucity of data, we conducted an exploratory study to estimate the incidence of post-colonoscopy infections in this population and to generate hypotheses regarding potential risk factors that can be tested in future prospective trials.

Methods

Study Design and Patients

Patients listed for liver transplantation from 1 January 2019 to 31 December 2023 at the University Hospital of Leuven (UZL), Belgium, were included.

We performed a retrospective single centre cohort analysis of this population to investigate incidence of possible post-colonoscopy infection (as defined below). We included only patients over the age of 18 that were screened and ultimately listed for transplantation. Included patients underwent a screening colonoscopy in our centre in the last five years prior to listing and were observed for at least 24 hours (up until 72 hours) post-

Correspondence to: Hannah van Malenstein, Department of Gastroenterology and Hepatology, University Hospital Gasthuisberg, KU Leuven, Herestraat 49, 3000 Leuven, Belgium.

Email: hannah.vanmalenstein@uzleuven.be

Submission date: 28/03/2026

Acceptance date: 30/05/2026

colonoscopy. Patients who underwent a colonoscopy in a referring centre, patients with <24 hours of observation and patients with an emergency indication (such as bleeding) were excluded.

Possible infection was defined as either the development of fever $\geq 38^{\circ}\text{C}$ post-procedure, newly developed white blood cell (WBC) count of more than 12,000 per microliter, bacteraemia or need for antibiotics within 72 hours.

Data collection

Basic demographic information at the time of endoscopy was collected including age, sex, aetiology and severity of liver disease (using MELD and Child-Pugh scores), presence of ascites (grade 1-3 according to European Association for the Study of the Liver clinical practice guidelines 2010), hepatic hydrothorax, hepatic encephalopathy (graded according to West-Haven criteria), oesophageal varices (graded according to the Paquet classification), therapeutic portosystemic shunt (either surgically or as transjugular intrahepatic portosystemic shunt), vital signs peri-procedurally (up until 72 hours after colonoscopy), laboratory values (WBC count, C- reactive protein (CRP), thrombocyte count, International Normalized Ratio (INR), sodium, serum creatinine, albumin and bilirubin), along with comorbid medical conditions such as presence of diabetes, smoking status as well as concomitant antibiotic or immunosuppressive usage. Laboratory values were used to calculate MELD and Child-Pugh scores.

Data of the colonoscopy procedure including pre-medication, bowel preparation adequacy (reported as Boston Bowel Preparation Score (BBPS)), caecal intubation rate and time, withdrawal time, polyp

resection and size (categorized as more or equal as versus less than 10 mm), presence of diverticulosis, sedation type (anaesthesia monitored care with propofol/general anaesthesia or endoscopist administered sedation with midazolam and pethidine), the concomitant performance of upper endoscopy, were collected. A BBPS score <6 or scoring ≤ 1 in any segment was defined as an insufficient bowel preparation.

Statistical analysis

Statistical analysis was performed using SPSS version 28, 2021 (IBM).

Categorical variables were compared with the Fisher Exact test and continuous variables were compared with the student t-test and Mann-Whitney U test. Variables with a p-value <0.10 in univariate analysis were considered potential candidates for further exploration. These were entered into a multivariable logistic regression model using a backward stepwise approach. However, given the limited number of outcomes relative to the number of predictors, the results of this multivariable model are considered exploratory and prone to instability.

Ethical approval

This study was approved by the Ethics Committee of the Catholic University of Leuven (study reference number: MP030955).

Results

A total of 460 patients were listed for liver transplantation between 1 January 2019 and 31

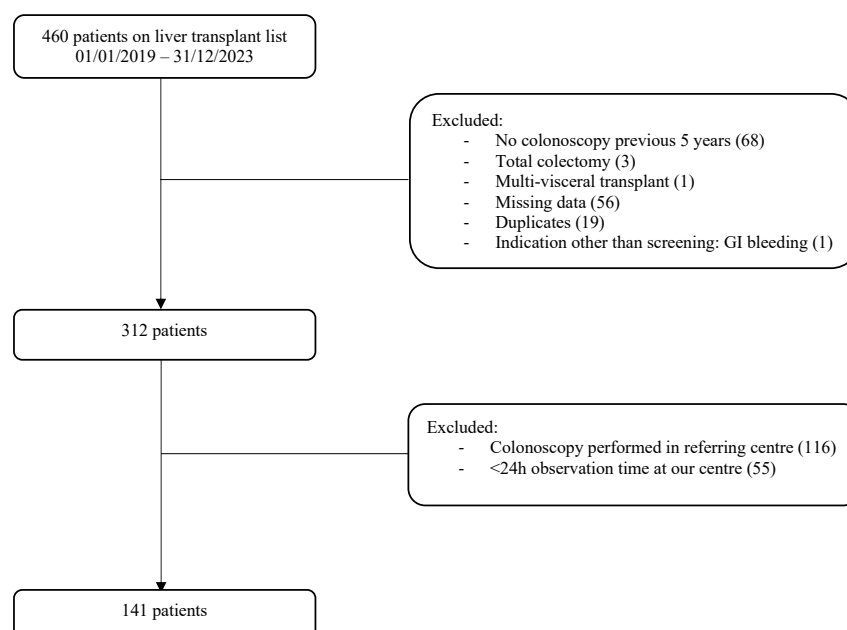


Figure 1. — Flowchart patient inclusion.

Table 1. — Patient-related characteristics.

	Patients (n=141)
Age in years, median (IQR)	60 (50-67)
Male sex, n (%)	79 (56.0)
Cause of Liver Disease, n (%)	
- Alcoholic liver disease	43 (30.5)
- MASLD	27 (19.1)
- Cholestatic liver disease (PSC/PBC)	18 (12.8)
- PLD	8 (5.7)
- Viral hepatitis	6 (4.3)
- AIH	6 (4.3)
- Other	33 (23.4)
Presence or history of HCC, n (%)	40 (28.4)
Cirrhosis, n (%)	101 (71.6)
Blood serum parameters	
- Creatinine (mg/dL), median (IQR)	0.8 (0.7-1.1)
- Albumin (g/L), mean (SD)	35.7 (±6.5)
- Bilirubin (mg/dL), mean (SD)	1.81 (±5.1)
- INR, mean (SD)	1.4 (±0.5)
- Sodium, mean (SD)	138.8 (±2.55)
MELD score, median (IQR)	14 (10-19)
Child-Pugh class, n (%)	
- A	2 (1.4)
- B	97 (68.8)
- C	42 (29.8)
Oesophageal varices ≥ grade 2, n (%)	42 (29.8)
Ascites ≥ grade 2, n (%)	55 (39.0)
Hepatic hydrothorax, n (%)	8 (5.7)
Patent therapeutic portosystemic shunt, n (%)	12 (8.5)
Hepatic encephalopathy, n (%)	
- none	58 (41.1)
- grade 1	47 (33.3)
- grade ≥ 2	36 (25.5)
Antibiotic use, n (%)	
- rifaximin	24 (17.0)
- other	19 (13.5)
Immunosuppressive medication, n (%)	22 (15.6)
Diabetes, n (%)	38 (27.0)
Smoking, n (%)	
- actively	15 (10.6)
- history	64 (45.4)
- never	62 (44.0)
Abbreviations: MASLD = metabolic dysfunction-associated steatotic liver disease, PSC = primary sclerosing cholangitis, PBC = primary biliary cholangitis, PLD = polycystic liver disease, AIH = autoimmune hepatitis, HCC = hepatocellular carcinoma, MELD = model for end-stage liver disease.	

December 2023 at the Catholic University Hospital of Leuven (UZL), Belgium. One hundred and forty-one (141) patients met the inclusion criteria (Fig. 1).

Patients were excluded from the study for the following reasons: no available colonoscopy report within the past five years (n = 68); history of colectomy

(n = 3) or multivisceral transplantation (n = 1); duplicate listings or re-listings without a renewed colonoscopy (n = 19); missing essential data (n = 55); colonoscopy performed for an indication other than screening (n = 1, gastrointestinal bleeding); colonoscopy performed at the referring centre rather than at the study site (n = 116); and an observation period of less than 24 hours post-colonoscopy at UZL (n = 55).

Patient characteristics

Patient characteristics are displayed in Table 1. Seventy-nine patients were male (56.0%), median age at colonoscopy was 60 years old (IQR 50-67). Underlying liver disease was either alcohol-related liver disease (30.5%), metabolic dysfunction associated steatotic liver disease (MASLD, 19.1%), primary sclerosing cholangitis (6.4%), primary biliary cholangitis (6.4%), polycystic liver disease (5.7%), viral (4.0%), autoimmune liver disease (4.0%) or other (23.4%) pathology. Forty patients (28%) had an active hepatocellular carcinoma (HCC) or a history of HCC when listed. The majority of patients had cirrhosis (n=101, 71.6%).

The median MELD score was 14 (IQR 10-19). The majority of patients were Child-Pugh B (n=97, 68.8%), a smaller percentage Child Pugh C (n=42, 29.8%) and Child Pugh A (n=2, 1.4%). Ascites grade 2 or more was present in 55 patients (39.0%) and eight patients (5.7%) had a hepatic hydrothorax. Forty-two patients (29.8%) had oesophageal varices grade 2 or more. Twelve patients (8.5%) had a therapeutic portosystemic shunt.

Twenty-four patients were on rifaximin (17.0%), while nineteen patients were on different antibiotics (13.5%) at the time-point of the procedure. Twenty-two patients were on immunosuppressive drugs (15.6%).

Fifteen patients were actively smoking (10.6%), while fifty-four had a history of smoking (38.3%). Thirty-eight patients (27.0%) had some form of diabetes.

Procedure related characteristics

Procedure related characteristics are displayed in Table 2. In 94 patients (66.7%) the BBPS score

was ≥ 6 , in 41 patients (29.1%) the bowel preparation was inadequate and in six patients a different bowel preparation score was used. Ninety-seven patients (68.8%) had concurrent upper endoscopy performed. Eighty-two patients (58.2%) were sedated using midazolam and pethidine, 58 patients (41.1%) had anaesthesia-monitored care, and one patient underwent colonoscopy without sedation. Diverticulosis was reported in 29 patients (20.5%). Polypectomy was performed at least once in 67 patients (47.5%). In 37 patients (26.2%) multiple polyps were removed. Only three patients underwent endoscopic mucosal resection (EMR), no endoscopic submucosal dissections were performed. Caecal intubation time and withdrawal time was not reported systematically and was not further analysed.

Post-procedural infections

A total of nine (6.4%) potential infectious events post-colonoscopy were identified. Eight patients developed fever within 24 hours following the procedure. Among these, blood cultures were obtained in seven cases: one was positive for *Escherichia coli* and another for *Parabacteroides* species; the remaining five cultures were negative. One patient demonstrated a pulmonary infiltrate on chest radiography. Another patient, despite being afebrile, exhibited an elevated CRP level; diagnostic paracentesis revealed leucocytosis consistent with spontaneous bacterial peritonitis. Antibiotic therapy was initiated in five of the nine cases. All nine patients with post-procedural infection had cirrhosis.

In univariate analysis, four variables were significantly associated with post-procedural infection (Table 3). Patients in the infection group more frequently had a higher Child-Pugh score (9.9 ± 1.5 vs 8.7 ± 1.5 , $p = 0.04$), ascites grade 2 or 3 (77.8% vs 36.4%, $p = 0.03$), higher INR (2.0 ± 0.6 vs 1.5 ± 0.4 , $p = 0.004$) and presence of diverticulosis (55.6% vs 18.2%, $p = 0.02$). Variables with a p -value < 0.10 in univariate analysis were entered into a backward stepwise multivariable logistic regression model (Table 4).

In the exploratory multivariable analysis, neither

Table 2. — **Procedure-related characteristics.**

	Patients (n=141)
Polypectomy performed, n (%)	67 (47.5)
BBPS, median (IQR)	6 (5-8)
Diverticulosis, n (%)	29 (20.6)
Sedation type, n (%)	
- Anaesthesia-monitored care (propofol)	58 (41.1)
- Endoscopist administered sedation (midazolam + pethidine)	82 (58.2)
- No sedation	1 (0.7)
Concurrent upper endoscopy, n (%)	97 (68.8)
Abbreviations: BBPS = Boston bowel preparation score	

Table 3. — Risk factors for post-colonoscopy infection.

	Infection following colonoscopy		p-value
	No (n = 132)	Yes (n = 9)	
Age at colonoscopy in years, mean with SD	57.2 ± 12.5	59.8 ± 8.2	0.47
Male sex, n (%)	72 (54.5)	7 (77.8)	0.32
MELD score, mean with SD	14.7 ± 6.4	17.6 ± 5	0.11
Child-Pugh score, mean with SD	8.7 ± 1.5	9.9 ± 1.5	0.04
Child-Pugh classification, n (%)			
A	2 (1.5)	0 (0)	1
B	92 (69.7)	5 (55.6)	0.46
C	38 (28.8)	4 (44.4)	0.45
Diabetes mellitus, n (%)	34 (25.8)	4 (44.4)	0.25
Smoking, n (%)			
Active smoking	14 (10.6)	1 (11.1)	1
History of smoking	59 (44.7)	5 (55.6)	0.73
Non-smoking	59 (44.7)	3 (33.3)	0.73
Cirrhosis present, n (%)	92 (69.7)	9 (100)	0.06
Hepatic hydrothorax present, n (%)	7 (5.3)	1 (11.1)	0.42
Ascites grade ≥ 2, n (%)	48 (36.4)	7 (77.8)	0.03
Encephalopathy grade ≥ 2, n (%)	33 (25.0)	3 (33.3)	0.69
Patent therapeutic portosystemic shunt present, n (%) *either surgical or TIPSS	11 (8.3)	1 (11.1)	0.56
Oesophageal varices ≥ grade 2, n (%)	39 (29.5)	3 (33.3)	1
Rifaximin use, n (%)	23 (17.4)	1 (11.1)	1
Antibiotics other than rifaximin, n (%)	17 (12.9)	2 (22.2)	0.35
Immune suppression therapy, n (%)	21 (15.9)	1 (11.1)	1
Laboratory			
White blood cell count (10x9/L)	5.3 ± 2.3	4.8 ± 2.0	0.97
Platelet count (10x9/L)	137.8 ± 77.9	97.8 ± 41.6	0.14
Total bilirubin (mg/dL)	3.8 ± 5.2	2.9 ± 2.7	0.83
Creatinine (mg/dL)	1.0 ± 0.7	1.0 ± 0.4	0.73
Albumin (g/L)	36.3 ± 6.6	35.0 ± 2.8	0.75
INR	1.5 ± 0.4	2.0 ± 0.6	0.004
Sodium (mmol/L)	138.8 ± 4.07	135.5 ± 3.91	0.39
Polypectomy performed, n (%)	63 (47.7)	4 (44.4)	1
BBPS, median (IQR)	6 (3-8)	6 (5-7)	0.18
Diverticulosis, n (%)	24 (18.2)	5 (55.6)	0.02
Sedation type, n (%)			
Anaesthesia-monitored care (propofol)	53 (40.2)	5 (55.6)	0.49
Endoscopist administered sedation (midazolam + pethidine)	78 (59.1)	4 (44.4)	0.49
No sedation	1 (0.8)	0 (0)	1
Concurrent upper endoscopy, n (%)	91 (68.9)	6 (66.7)	1
Abbreviations: MELD = model for end-stage liver disease, TIPSS = transjugular intrahepatic portosystemic shunt, BBPS = Boston bowel preparation score.			

INR (OR 3.58; 95% CI 0.99-13.6; $p = 0.051$) nor the presence of diverticulosis (OR 3.85; 95% CI 0.86-17.8; $p = 0.07$) reached conventional statistical significance ($p < 0.05$). However, the wide confidence intervals reflect the statistical uncertainty inherent in the analysis due

to the low event rate, and the point estimates suggest a trend that may be clinically meaningful and warrants further investigation.

There were no statistically significant differences with respect to the presence of diabetes, hepatic hydrothorax,

Table 4. — **Multivariate backward logistic regression analysis.**

Characteristic	OR	95% CI	p-value
Ascites grade ≥ 2	3.77	0.79 – 27.2	0.12
INR	3.58	0.99 – 13.6	0.051
Diverticulosis present	3.85	0.86 – 17.8	0.07
Abbreviations: CI = Confidence Interval, OR = Odds Ratio.			

therapeutic portosystemic shunt, grade ≥ 2 oesophageal varices, smoking status, use of antibiotics (including rifaximin) or immunosuppressive medication, MELD score, performance of polypectomy, adequacy of bowel preparation, type of sedation, or concurrent upper endoscopy. Notably two patients (22.2%) with possible infection were already on quinolone antibiotics, of which one had positive blood cultures with *Parabacteroides* species.

Discussion

In this exploratory analysis of liver transplant candidates undergoing screening colonoscopy, we observed a potential signal for infectious complications, with an event rate of 6.4% in the overall cohort and 8.9% in the cirrhotic subgroup. A key finding of this study is that every infectious complication occurred in a patient with cirrhosis; the non-cirrhotic subgroup experienced no events. This observation strongly suggests that the infection risk post colonoscopy in liver transplant candidates is driven by the presence and severity of underlying cirrhosis rather than by the transplant listing status per se. While this rate appears higher than the ~1% baseline risk reported in cirrhotic patients not undergoing procedures (8), the retrospective design and lack of a control group preclude a definitive causal attribution to the colonoscopy itself. Nonetheless, the microbiological profile of documented bacteraemia (*Escherichia coli*, *Parabacteroides* species) offers a hypothesis that the gut may one of the sources of these events (9). The occurrence of a pulmonary infiltrate post-sedation provides supportive evidence for a procedural aetiology in one of our cases.

Univariate analysis highlighted several factors that may be associated with infectious complications, including markers of liver disease severity (Child-Pugh score, INR, ascites) and the presence of diverticulosis. In multivariate analysis, diverticulosis and INR showed a trend towards an association (resp. p-values 0.07 and 0.051), ascites and Child-Pugh score were no longer statistically significant. The loss of significance for the Child-Pugh score is not unexpected, given that it is a composite score incorporating multiple variables, including INR. These findings align with the biological plausibility that sicker patients with portal hypertension and potential gut barrier disruption are most vulnerable. The higher prevalence of diverticulosis in the infection group (55.6% vs. 18.2%) generates the hypothesis that

diverticula might act as bacterial reservoirs, increasing the risk of translocation during colonic insufflation and scope trauma. Because of the low event count, however, these multivariable associations must be interpreted with caution; they are susceptible to overfitting and require confirmation in adequately powered cohorts. Future prospective investigations should therefore specifically enrol cirrhotic patients, ideally stratifying them by disease severity (e.g., Child Pugh class, presence of ascites, INR) and by the presence of diverticulosis.

Notably, neither chronic antibiotic prophylaxis (including rifaximin) nor immunosuppressive medication use demonstrated a statistically significant protective or detrimental effect on infection risk. This lack of association may reflect the heterogeneity of antimicrobial regimens (varying spectra of activity and targets) and immunosuppressive agents (ranging from low-dose azathioprine to calcineurin inhibitors) within the cohort.

Although no association was observed between inadequate bowel preparation and post-colonoscopy infections in our cohort, a notably high prevalence of BBPS < 6 was identified. Adequate bowel preparation is necessary for a thorough and complete colonoscopic examination. The European Society of Gastrointestinal Endoscopy guidelines recommend assessing and reporting bowel preparation, for example with the BBPS (10, 11), ranging bowel cleanliness from unsatisfactory “0” to excellent “3” for the 3 broad regions: right, transverse and left colon. Inadequate preparation – defined as a BBPS score < 6 or scoring ≤ 1 in any segment – is linked with decreased polyp and adenoma detection rates (resp. PDR and ADR), increased caecal intubation time (CIT) and increased interval cancer (12). Prospective studies have shown cirrhotic patients to have a worse bowel preparation score than healthy control patients (13, 14). Rescheduling colonoscopy is recommended but associated with increased costs, time-consuming for the physician and an inconvenience for the patient. Our study population of which 37 patients (27,4%) reported as a BBPS < 6 , contains a large subset of cirrhotic patients. However, an equal number of patients (29,7%) of non-cirrhotic patients also had low BBPS scores. A possible explanation why non-cirrhotic patients in this cohort did not achieve a good BBPS is because of underlying pathology such as polycystic disease, diabetes with impaired gastro-intestinal motility, that may inhibit adequate cleansing compared to a healthy population undergoing

screening colonoscopy. Furthermore, the documented cases of bacteraemia involving enteric organisms (*E. coli*, *Parabacteroides*) raise questions about potential sources, including inadequate bowel preparation or endoscope-related transmission. Due to rising antimicrobial resistance rates and multidrug resistant bacteria adhering to endoscopes, reprocessing protocols have become stricter, even suggesting the use of single-use disposable endoscopes as a potential strategy to mitigate this risk, particularly in high-risk populations (15).

In our cohort, no colorectal cancer was identified, consistent with the low CRC yield (0.2%) and advanced adenoma yield (5.4%) reported in the largest published pre-LT colonoscopy series (7). This raises important questions about the risk-benefit balance of routine screening colonoscopy in this population, especially given that only approximately half of evaluated patients ultimately proceed to transplantation and are therefore unnecessarily exposed to procedural risks (7). On the one hand, the two-fold increased CRC risk in cirrhotic patients, which persists post-transplant (pooled SIR 2.16), and the potential for undiagnosed malignancy to progress rapidly under immunosuppression argue in favour of pre-LT screening (16). On the other hand, deferring colonoscopy until after transplantation may yield higher-quality examinations with fewer caecal intubation failures and better bowel preparation, and high-risk polyps are newly detected in 4.2% of recipients at first post-LT colonoscopy despite a reportedly normal pre-LT exam (17). Non-invasive alternatives such as the faecal immunochemical test (FIT) or flexible sigmoidoscopy combined with FIT could serve as triage tools for highly decompensated patients unlikely to tolerate total colonoscopy. However, data in cirrhotic populations remain scarce, and the modest sensitivity of FIT for advanced adenomas remains a concern. Although cirrhosis-related thrombocytopenia and coagulopathy could theoretically increase false-positive FIT results, this was not observed in the retrospective analysis by Ting et al (18). In our centre, colonoscopy findings did not alter transplant eligibility in any patient. These considerations suggest that screening strategies may need to be individualised by disease severity, and future prospective studies should evaluate whether deferring colonoscopy to the early post-transplant period in carefully selected decompensated patients is a safe alternative.

Finally, this study has several inherent limitations that warrant careful consideration. Its retrospective, single-centre design and modest cohort size ($n=141$) may limit the generalizability of our findings. For example, procedural sedation practices at our institution differ from many national and international centres, with a majority of patients (58.2%) receiving endoscopist-administered midazolam and pethidine rather than anaesthesiologist-monitored propofol sedation. Compared with propofol, midazolam-based sedation in

cirrhotic patients carries a risk of prolonged sedation and exacerbation of subclinical hepatic encephalopathy; propofol, by contrast, offers a more favourable pharmacokinetic profile with faster, more predictable recovery and no evidence of encephalopathy worsening (19). This variation in sedation protocols may influence sedation depth, aspiration risk and consequently infection rates, potentially affecting the comparability of our results with centres utilizing different sedation approaches (20). Furthermore, the low absolute number of infectious events ($n=9$) constrained statistical power, precluding robust multivariable analysis to establish independent risk factors (e.g., disentangling ascites from overall Child-Pugh severity) and increasing the risk of Type II errors (e.g., missing true associations with antibiotic use). The backward stepwise logistic regression model used is inherently unstable with so few events and is at high risk of overfitting; therefore, the reported associations with INR and diverticulosis are strictly hypothesis-generating.

Although the mandatory post-procedural observation period was relatively short (minimum 24 hours), patients discharged before completion of this observation period were excluded from the analysis. This exclusion criterion may have introduced selection bias, as patients who were clinically stable and discharged early were likely at lower risk of developing post-procedural infection. Consequently, the observed infection rate may be overestimated compared with an unselected population. While late-onset or mild infectious manifestations occurring after discharge could have been missed, clinically relevant infections would likely have resulted in hospital re-admission, partially mitigating the risk of substantial outcome misclassification.

Data completeness posed additional challenges: key procedural metrics (including caecal intubation and withdrawal times) were not systematically recorded, preventing assessment of their role in infection risk. Furthermore, while our endpoint captured objective markers of potential infection (fever $\geq 38^{\circ}\text{C}$, leucocytosis $>12,000/\mu\text{L}$, bacteraemia, need for antibiotics), these findings do not necessarily equate to clinically significant infections or procedure-attributable morbidity/mortality. Finally, the absence of a matched control group not undergoing colonoscopy hinders definitive attribution of observed infections to the procedure versus the underlying disease state. Moreover, patients frequently underwent concurrent semi-invasive procedures during pre-transplant evaluations (e.g., coronary angiography, dental sanitation and/or extraction) that could independently cause bacteraemia or serve as alternative infection sources.

In conclusion, this exploratory study indicates that cirrhotic liver transplant candidates, but not those without cirrhosis, are vulnerable to infectious complications following colonoscopy. Because of the low event rate, the multivariable findings must be considered

strictly hypothesis-generating. Disease severity and diverticulosis appear to be potential risk modifiers in this subgroup. These findings underline the need for prospective studies in cirrhotic patients that not only validate risk factors and guide prophylactic strategies, but also assess the safety of deferring colonoscopy to the post-transplant period or using alternative screening tools such as FIT and sigmoidoscopy. Given the significant methodological limitations, including the low event rate and potential selection bias, these findings should be considered preliminary. They serve to inform the design of larger, adequately powered prospective studies that are urgently needed to confirm these associations, clarify the role of the procedure itself versus the underlying disease, and ultimately guide evidence-based recommendations for prophylaxis and post-procedural monitoring in this high-risk population.

References

- Watabe H, Yamaji Y, Okamoto M, Kondo S, Ohta M, Ikenoue T, et al. Risk assessment for delayed hemorrhagic complication of colonic polypectomy: polyp-related factors and patient-related factors. *Gastrointest Endosc.* 2006;64:73–8. doi: 10.1016/j.gie.2006.02.054
- Arora G, Mannalithara A, Singh G, Gerson LB, Triadafilopoulos G. Risk of perforation from a colonoscopy in adults: a large population-based study. *Gastrointest Endosc.* 2009;69:654–64. doi: 10.1016/j.gie.2008.09.008
- Chan YC, Chen CL, Wang CC, Lin CC, Yong CC, Chiu KW, et al. Extremity risk factors of sepsis for gastrointestinal endoscopy in patients with liver cirrhosis. *BMC Gastroenterol.* 2022;22:54. doi: 10.1186/s12876-022-02124-0
- Fernández J, Acevedo J, Wiest R, Gustot T, Amoros A, Deulofeu C, et al. Bacterial and fungal infections in acute-on-chronic liver failure: prevalence, characteristics and impact on prognosis. *Gut.* 2018;67:1870–80. doi: 10.1136/gutjnl-2017-314240
- Jalan R, Saliba F, Pavesi M, Amoros A, Moreau R, Ginès P, et al. Development and validation of a prognostic score to predict mortality in patients with acute-on-chronic liver failure. *J Hepatol.* 2014;61:1038–47. doi: 10.1016/j.jhep.2014.06.012
- Piano S, Singh V, Caraceni P, Maiwall R, Alessandria C, Fernandez J, et al. Epidemiology and effects of bacterial infections in patients with cirrhosis worldwide. *Gastroenterology.* 2019;156:1368–80.e10. doi: 10.1053/j.gastro.2018.12.005
- Oey RC, van Tilburg L, Erler NS, Metselaar HJ, Spaander MCW, van Buuren HR, et al. The yield and safety of screening colonoscopy in patients evaluated for liver transplantation. *Hepatology.* 2019;69:2598–607. doi: 10.1002/hep.30562
- Huang RJ, Banerjee S, Friedland S, Ladabaum U. Risk of ambulatory colonoscopy in patients with cirrhosis: a propensity-score matched cohort study. *Endosc Int Open.* 2020;8:E1495–501. doi: 10.1055/a-1242-9958
- Ghassemi S, Garcia-Tsao G. Prevention and treatment of infections in patients with cirrhosis. *Best Pract Res Clin Gastroenterol.* 2007;21:77–93. doi: 10.1016/j.bpg.2006.07.004
- Kaminski MF, Thomas-Gibson S, Bugajski M, Bretthauer M, Rees CJ, Dekker E, et al. Performance measures for lower gastrointestinal endoscopy: a European Society of Gastrointestinal Endoscopy (ESGE) quality improvement initiative. *Endoscopy.* 2017;49:378–97. doi: 10.1055/s-0043-103411
- Lai EJ, Calderwood AH, Doros G, Fix OK, Jacobson BC. The Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. *Gastrointest Endosc.* 2009;69:620–5. doi: 10.1016/j.gie.2008.05.057
- Atkin W, Wooldrage K, Brenner A, Martin J, Shah U, Perera S, et al. Adenoma surveillance and colorectal cancer incidence: a retrospective, multicentre, cohort study. *Lancet Oncol.* 2017;18:823–34. doi: 10.1016/S1470-2045(17)30187-0
- Hassan C, Fuccio L, Bruno M, Pagano N, Spada C, Carrara S, et al. A predictive model identifies patients most likely to have inadequate bowel preparation for colonoscopy. *Clin Gastroenterol Hepatol.* 2012;10:501–6. doi: 10.1016/j.cgh.2011.12.037
- Salso A, De Leonardi F, Lionetti R, Lenci I, Angelico M, Telese A, et al. Standard bowel cleansing is highly ineffective in cirrhotic patients undergoing screening colonoscopy. *Dig Liver Dis.* 2015;47:523–5. doi: 10.1016/j.dld.2015.02.013
- Deb A, Perisetti A, Goyal H, Aloysius MM, Sachdeva S, Dahiya D, et al. Gastrointestinal endoscopy-associated infections: update on an emerging issue. *Dig Dis Sci.* 2022;67:1718–32. doi: 10.1007/s10620-022-07441-8
- Komaki Y, Komaki F, Micic D, Ido A, Sakuraba A. Risk of colorectal cancer in chronic liver diseases: a systematic review and meta-analysis. *Gastrointest Endosc.* 2017;86(1):93–104.e5. doi:10.1016/j.gie.2016.12.009
- Ryu DG, Liu H, Lee SS, Yoon KT, Brahmania M. Appropriate Timing and Interval for Surveillance Colonoscopy after Liver Transplantation Based on a Single-Centre Experience. *Can Liver J.* 2025;8(1):39–48. doi:10.3138/canlivj-2024-0041
- Ting PH, Lin XH, Jiang JK, Luo JC, Chen PH, Wang YP, et al. The factors associated with negative colonoscopy in screening subjects with positive immunochemical stool occult blood test outcomes. *J Chin Med Assoc.* 2018;81(9):759–765. doi:10.1016/j.jcma.2017.11.015
- Jeong J, Jung K, Seo KI, Yun BC, Han BH, Lee SU, et al. Propofol alone prevents worsening hepatic encephalopathy rather than midazolam alone or combined sedation after esophagogastroduodenoscopy in compensated or decompensated cirrhotic patients. *Eur J Gastroenterol Hepatol.* 2020;32(8):1054–1061. doi:10.1097/MEG.0000000000001755
- Arnaert S, Vandebroek V, Persyn D, Cool M, Lambrecht G, Desmet G, et al. A survey among Flemish gastroenterologists about endoscopic sedation practices in colorectal cancer screening. *Acta Gastroenterol Belg.* 2023;86:527–32. doi: 10.51821/86.4.12145