Impact of COVID-19 on the outcomes of gastrointestinal surgery

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Abstract
COVID-19 pandemic has brought a paradigm shift in the treatment of various surgical gastrointestinal disorders. Given the increasing number of patients requiring hospitalization and intensive care for SARS-CoV-2 infections, various surgical departments worldwide were forced to stop or postpone elective surgeries to save the health resources for COVID-19 patients. Since the declaration of the COVID-19 pandemic by the World Health Organization on 12th March 2020, the recommendations from the surgical societies kept evolving to help the surgeons in making informed decisions regarding patient care. Moreover, various socio-economic and epidemiological factors have come into play while deciding the optimal approach towards patients requiring gastrointestinal surgery. Surgeries for many abdominal diseases such as acute appendicitis and acute calculous cholecystitis were postponed. Elective surgeries were triaged based on the urgency of performing the surgical procedure, the hospital burden of COVID-19 patients, and the availability of healthcare resources. Various measures were adopted such as preoperative screening for SARS-CoV-2 infection, use of personal protective equipment, and the COVID-19-free surgical pathway to prevent perioperative SARS-CoV-2 transmission. In this article, we have reviewed the recent studies reporting the outcomes of various gastrointestinal surgeries in the COVID-19 pandemic era and the recommendations from various surgical societies on the safety precautions to be followed during gastrointestinal surgery.

Keywords SARS-CoV-2 · COVID-19 · Liver transplant · Bariatric surgery · Colorectal cancer

Introduction
Since the first declaration of the COVID-19 outbreak in Wuhan, China, in December 2019, the disease has spread rapidly across the globe affecting more than 96 million individuals and led to more than 2 million deaths in 13 months [1]. The exponential surge in the number of patients affected by COVID-19 has led to an unprecedented crisis in health care facilities. Limited health care resources such as personal protective equipment, intensive care facilities forced the surgical departments throughout the globe to re-schedule their surgeries by postponing elective cases and performing only emergency life-saving procedures [1–3]. At the beginning of 2020, there were reports of postoperative COVID-19 after elective surgeries with a lack of evidence on its impact on surgical outcomes [4, 5]. Hence, many surgical societies recommended postponing elective surgeries until the availability of health care resources and reduction in the burden of COVID-19 cases [6, 7].

To facilitate evidence-based decision-making in the COVID-19 pandemic era, we have performed a detailed literature review and summarized the findings of studies reporting the impact of SARS-Cov-2 infection on the outcomes of gastrointestinal surgeries. Besides, we have provided an overview of the recommended surgical guidelines on the perioperative safety measures to prevent transmission of SARS-CoV-2 infection among the patients and health care workers and optimize the outcomes of abdominal surgeries.

Impact of COVID-19 pandemic on gastrointestinal surgical services

All the surgical services have been severely affected during this ongoing COVID-19 pandemic. In a study published in May 2020, it was estimated that during the 12
weeks of peak disruption due to the COVID-19 pandemic, about 28.4 million surgeries would be canceled worldwide, which would require 45 weeks to clear the backlog of surgeries if the surgical centers increase their routine surgical volume by 20% after the recovery from the pandemic [8]. However, this estimate is far from reality as the pandemic is still not over. Elective surgeries are still being postponed at several centers worldwide to take care of the COVID patients with limited health resources. In the United Kingdom, nearly all elective bariatric surgeries were postponed in April 2020, the peak COVID-19 pandemic [9]. Various other abdominal surgeries, including colorectal surgeries [10, 11], solid organ transplants [12], were severely affected in 2020.

In a Spanish study comparing acute care surgeries performed before and during the COVID pandemic, the authors reported significantly fewer laparoscopic surgeries in the pandemic era (43.3% vs. 63.6%, \( p = 0.001 \)) [13]. The reasons were fear of spreading SARS-CoV-2 infection with laparoscopic aerosols and fewer surgeries performed for acute cholecystitis during the pandemic era. The authors reported about a 59% decrease in the number of emergency surgeries during the pandemic. The time from onset of symptoms to patient arrival to the emergency department was longer (44.6 h vs. 71 h, \( p < 0.001 \)). The surgeries for bowel obstruction and ventral hernia increased, while that for acute cholecystitis decreased during the pandemic period. An Indian study by Kapoor et al. reported that only 314 gastrointestinal surgeries were performed from March to July 2020 compared to 914 surgeries during the same time in the previous year [14].

At the beginning of the COVID-19 pandemic, laparoscopy was believed to increase the risk of viral transmission based on the previous reports of viral aerosolization (HPV, HBV, HIV) due to the chimney effect of the smoke that escaped from the trocars [15]. Hence, many surgical societies recommended restricted use of laparoscopy and diathermy during the pandemic [16]. However, with accumulation of experience and clinical data analysis, it was found that there was no significant perioperative SARS-CoV-2 infection transmission among the patients and healthcare workers with laparoscopy [15, 17, 18]. Hence, the new recommendation was to perform laparoscopic surgeries using appropriate precautions such as personal protective equipment, smoke evacuation devices, if it was clearly beneficial to the patients and reduced their hospital stay [19, 20]. The CLOUD-19 collaborative group conducted an online survey in Italy and found that the proportion of surgeons performing less than 20% laparoscopic elective surgeries during the three phases (March–May, June–September, October–December 2020) of COVID-19 pandemic was 25.8%, 12.4% and 19.3%, respectively [21]. These findings indicated that the practice of laparoscopy in COVID-19 pandemic continues to remain restricted despite lack of evidence of SARS-CoV-2 transmission by surgical smoke.

COVID-19 pandemic has caused significant delay in the diagnosis and treatment of various gastrointestinal cancers [22–27]. The decline in number of surgeries in 2020 has been due to multiple factors including delayed diagnosis due to national lockdowns, hesitance of patients to visit hospital, cancelation of endoscopic activity and other cancer screening programs, and cancelations/postponement of elective surgeries due to shortage of hospital resources [25, 27, 28]. A study from United Kingdom (UK) reported that all non-emergent endoscopies were stopped for 6 weeks in March and April 2020 due to COVID-19 pandemic leading to significant reductions in diagnostic endoscopies and decreased the number of new cancer cases from 677 per week in the pre-COVID period to 283 per week in the COVID times [28]. Another UK study had estimated that about 5% and 16% increase in deaths is likely to occur from esophageal and colorectal cancer due to delay in diagnosis and therapeutic interventions [22]. According to a study by Sud et al., delay in cancer surgery by more than 3 months and 6 months may lead to > 17% and > 30% reduction in the survival of patients with stage 2 or 3 gastrointestinal cancers [26]. An international survey involving 76 centers across the world found that 50% curative and/or palliative treatments for liver cancer and 44% liver transplants were canceled during COVID-19 pandemic from March to June 2020 [25].

Impact of preoperative COVID-19 on the postoperative outcomes

Various studies have been published in the literature to report the outcomes of gastrointestinal surgery in the COVID-19 pandemic. In this review article, we have summarized the findings of key original articles and meta-analysis which can help the clinicians in day-to-day practice (Table 1).

Emergency surgery

An initial study from Wuhan, China comparing outcomes of eight COVID-19 patients with 22 non-COVID patients requiring emergency abdominal surgery found no significant impact of COVID-19 on the postoperative outcomes, namely, the blood parameters, respiratory support, and mortality [29]. The authors concluded that patients with acute abdomen should be offered surgical treatment if required, irrespective of the COVID-19 status. In another study from Wuhan, the authors compared outcomes of six patients with preoperative COVID-19 pneumonia and 28 patients without SARS-CoV-2 infection who underwent emergency surgery [30]. They reported a higher duration of hospital stay in COVID patients but no difference in the postoperative
### Table 1: Studies reporting the postoperative outcomes of various elective emergency gastrointestinal surgeries in the COVID pandemic era

| Sr. No | Authors | Country of origin | Study period | Number of patients in study group | Number of patients in control group | Type of surgery | Diagnosis/operative details | Postoperative morbidity | Postoperative mortality | Comments |
|--------|---------|--------------------|--------------|-----------------------------------|-------------------------------------|-----------------|-----------------------------|------------------------|------------------------|----------|
| 1      | Cai M et al. [29] | China | 15 January 2020–15 March 2020 | 8 (COVID positive) | 22 (COVID negative) | EAS | Appendectomy, Gastrectomy, Enterocolectomy, Cholecystectomy, Pancreateojunostomy, Gastric perforation repair | – | 12.5% vs. 13.6% | – |
| 2      | Zhao N et al. [30] | China | 2 February 2020–18 March 2020 | 6 (COVID positive) | 28 (COVID negative) | Emergency surgery | Acute appendicitis, Gastrointestinal perforation, Intestinal obstruction, Gangrenous cholecystitis, Bladder rupture | 33% vs. 18%, \( p = 0.580 \) | 175 vs. 11%, \( p = 0.560 \) | Emergency surgery facilitated early resolution of pulmonary inflammation |
| 3      | Cano-Valderrama O et al. [13] | Spain | 16 March 2020–26 April 2020 (COVID era); 11 March 2019–21 April 2019 (pre-COVID era) | 117 (COVID era) | 285 (pre-COVID era) | ACS | Acute appendicitis, Anorectal abscess, Complications of previous elective procedures, Acute cholecystitis, Bowel obstruction, Abdominal wall hernia | 47.1% vs. 34.7%, \( p = 0.002 \) (overall morbidity); 12.8% vs. 17.9%, \( p = 0.212 \) (reoperation); 17.1% vs. 22.8%, \( p = 0.203 \) (ICU admission); 11.9% vs. 10.2%, \( p = 0.598 \) (respiratory complication) | 4.3% vs. 6.7%, \( p = 0.358 \) | Laparoscopic surgery was performed in 57.82% cases |
| Sr. No | Authors                        | Country of origin | Study period               | Number of patients in study group | Number of patients in control group | Type of surgery               | Diagnosis/operative details                                                                 | Postoperative morbidity | Postoperative mortality | Comments                                                                                     |
|-------|--------------------------------|-------------------|----------------------------|-----------------------------------|-------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------|------------------------|-------------------------|-------------------------------------------------------------------------------------------|
| 4     | Seretis C et al. [36]          | United Kingdom    | 1 March 2020–31 May 2020   | 100 (COVID era)                  | –                                   | EAS                           | Appendectomy                  | 5% (overall respiratory complications); 3% (postoperative COVID infection)                 | 1%                     |                         | Laparoscopic surgery (35%), preoperative SARS-CoV-2 testing (49%)                        |
| 5     | Bozkurt H et al. [37]          | Turkey            | 11 March 2020–2 April 2020 | 25 (COVID era)                  | –                                   | EAS                           | Appendicitis                   | Two patients with suspected postoperative COVID                                             |                         | 8% (non-COVID causes of death)                                                          |
| 6     | Knisely A et al. [32]          | USA               | 17 March 2020–15 April 2020| 36 (COVID positive)             | 432 (COVID negative)               | Emergency surgery              | All surgical specialties       | 58.3% vs. 6%, *aRR* = 7.02 (serious complications); 36.1% vs. 16.4%, *aRR* = 1.34 (ICU admission) | 16.7% vs. 1.4%, *aRR* = 9.29 | –                       |                                                                             |
| 7     | COVIDSurg collaborative [31]    | Multicenter       | 1 January 2020–31 March 2020| 1128 (perioperative COVID)       | –                                   | Emergency surgery              | All surgical specialties       | 51.2% (pulmonary complications)                                                           | 23.8%                  | Male sex, age > 70 years, ASA grade > 3, malignant disease, emergency surgery and major surgery were predictors of mortality |
| Sr. No | Authors | Country of origin | Study period | Number of patients in study group | Number of patients in control group | Type of surgery | Diagnosis/operative details | Postoperative morbidity | Postoperative mortality | Comments |
|-------|---------|------------------|--------------|----------------------------------|-------------------------------------|----------------|----------------------------|------------------------|------------------------|----------|
| 8     | Doglietto F et al. [35] | Italy | 23 February 2020–1 April 2020 | 41 (COVID positive) | 82 (COVID negative) | Emergency—110 (89.4%), Elective—13 (10.4%) | General, neuro, orthopedic and vascular surgeries | OR 35.6 [95% CI 9.34–205.55] (pulmonary complications) OR 4.98 [95% CI 1.81–16.07] (surgical complications) | 19.5% vs. 2.45, OR 9.5 [95% CI 1.77–96.53] | – |
| 9     | COVIDSurg collaborative [33] | Multicenter | February 2020–24 May 2020 | 112 (history of COVID) | 448 (no COVID history) | Elective cancer surgery | All cancer surgeries | 10.7% vs. 3.6%, p = 0.004 (pulmonary complications) | - | Pulmonary complications were lowest in patients operated at least 4 weeks after SARS-CoV-2 positive swab test |
| 10    | COVIDSurg collaborative [39] | Multicenter | First recorder case at the study centers until 19 April 2020 | 2073 (COVID era) | 5792 (pre-COVID era) | Elective cancer surgery | Colorectal cancer | 3.8% (postoperative COVID); 4.9% (anastomotic leak); 34.2% vs. 27.2% (stoma formation) | 1.8% | Anastomotic leak, male sex, postoperative COVID, age > 70 years and advanced stage of the disease were predictors of mortality |
| 11    | Tejedor P, et al. [40] | Spain | 1 February 2020–31 May 2020 | 259 (COVID era) | – | Elective cancer surgery | Colorectal cancer | 7.7% (major complications); 5.7% reinterventions; 1.2% (postoperative COVID) | 0.7% | Median length of stay was 6 days |
| 12    | Shrikhande SV, et al. [41] | India | 23 March 2020–30 April 2020 | 494 (COVID era) | – | Elective and emergency cancer surgery | All cancer surgeries | 5.6% (major complications); 1% (postoperative COVID) | 0 | – |
| Sr. No | Authors                          | Country of origin | Study period                                         | Number of patients in study group | Number of patients in control group | Type of surgery                                      | Diagnosis/operative details | Postoperative morbidity | Postoperative mortality | Comments                                                                 |
|-------|----------------------------------|-------------------|------------------------------------------------------|----------------------------------|------------------------------------|------------------------------------------------------|----------------------------|------------------------|------------------------|--------------------------------------------------------------------------|
| 13    | Kapoor D et al.                  | India             | 24 March 2020–31 July 2020                           | 314 (COVID era)                  | –                                  | Elective gastrointestinal and HBP surgery           | Benign etiology—55% Malignant etiology—45%            | 3.5% (major complication); 0% (postoperative COVID) | 1%                     | Laparoscopic surgery was done in 43% cases                                |
| 14    | Singhal R, et al. (GENEVA collaborators) | Multicenter       | 1 May 2020–10 July 2020                              | 2001                             | –                                  | BMS                                                  | Sleeve gastrectomy—1142 (57%), Roux-en-Y gastric bypass—557 (28%) | 6.8% (30-day morbidity); 0.5% (postoperative symptomatic COVID) | 0.05%                  | No patient died due to postoperative COVID                                 |
| 15    | Maggi U et al.                   | Italy             | 23 February 2020–10 April 2020                       | 17 (COVID era)                   | –                                  | LT                                                  | –                                                        | 2 (11.7%) (postoperative COVID)                           | 1 (5.89%) (COVID-related) | –                                                                          |
| 16    | Varghese J et al.                | India             | 1 April 2020–31 July 2020                            | 31 (COVID era)                   | –                                  | Living donor LT                                      | Adult LT—21 Pediatric LT—10                           | 8 (25.8%) (major complications); 1 (3.2%) (postoperative COVID) | 2 (6.45%)               | None of the donors or healthcare workers developed COVID-19               |
| 17    | Challine A et al.                | France            | 17 March 2020–11 May 2020 (COVID era); 19 March 2019–13 May 2019 (pre-COVID era) | 5892 (COVID era) [574 (8.7%) (COVID positive)] | 9325 (pre-COVID era) | Elective digestive resections                       | Esophageal, gastric, colorectal, pancreatic and hepatic resections | 80% vs. 47% vs. 20% (symptomatic COVID vs. asymptomatic COVID vs. no COVID) | 3% vs. 2.5%, p = 0.1 | The surgical activity decreased by 37% in the lockdown period. Risk factors for mortality were asymptomatic COVID (OR: 2 [95%CI 1.27–3.05]) and symptomatic COVID (OR: 10.5 [95%CI 5.35–19.3]) |
The authors found that emergency surgery helped treat the surgical pathology and benefited in the early resolution of the pulmonary inflammation [30]. So, it was recommended that emergency surgery should be conducted, if required, with all the safety precautions to prevent SARS-CoV-2 transmission among other patients and medical staff members.

A Spanish study compared outcomes of emergency abdominal surgeries in 285 patients from the pre-COVID era with 117 patients during the COVID pandemic [13]. Out of the 117 patients in the COVID era, four patients were suspected, and three patients had confirmed SARS-CoV-2 infection. The overall morbidity rate was higher (47.1% vs. 34.7%, \( p = 0.002 \)) while the reoperation rate (12.8% vs. 17.9%, \( p = 0.212 \)) and mortality rate (4.3% vs. 6.7%, \( p = 0.358 \)) was similar in the two groups [13].

In an international multicenter study conducted by COV-IDSurg Collaborative involving 1128 surgical patients with perioperative SARS-CoV-2 infection [preoperative (within 7 days before surgery) in 294 patients and postoperative (up to 30 days after surgery) in 834 patients], the pulmonary complications and mortality were reported in 51.2% and 23.7% cases, respectively [31]. The factors associated with 30-day mortality included male sex, age > 70 years, American Society of Anesthesiologists (ASA) grade > 3, malignant disease, emergency surgery, and major surgery. Hence, the authors concluded that the threshold to perform surgery in patients with the risk factors mentioned above should be high [31].

In an American study of 468 patients undergoing emergency surgery, 36 patients had confirmed COVID-19 [32]. The perioperative serious complications rate [58.3% vs. 6%, adjusted relative risk (\( aRR = 7.02 \))], ICU admission rate (36.1% vs. 16.4%, \( aRR = 1.34 \)) and mortality rates (16.7% vs. 1.4%, \( aRR = 9.29 \)) were significantly higher in patients with COVID-19 [32].

Hence, SARS-CoV-2-infected patients requiring emergency surgery should be offered surgical treatment and strict protocol should be followed to prevent viral transmission to the health workers and other patients.

### Elective surgery

A multicenter comparative study of patients with \( n = 112 \) and without \( n = 448 \) history of SARS-CoV-2 infection undergoing elective cancer surgery was conducted [33]. The study found that previous SARS-CoV-2 infection was associated with an increased risk of postoperative pulmonary complications (10.7% vs. 3.6%, \( p = 0.004 \)). The authors also reported that the risk of pulmonary complications and mortality was lowest when the surgery was performed at least 4 weeks after the positive swab test in those with SARS-CoV-2 infection [33].

### Table 1 (continued)

| Sr. No | Authors | Country of origin | Study period | Number of patients in study group | Number of patients in control group | Type of surgery | Diagnosis/operative details | Postoperative morbidity | Postoperative mortality |
|-------|---------|-------------------|--------------|-----------------------------------|------------------------------------|----------------|-----------------------------|------------------------|------------------------|
| 18    | Jonker PKC et al. [72] | Netherlands | 27 February 2020–1 June 2020 | 161 COVID positive (after PSM) | 123 COVID positive (after PSM) | All elective and emergency surgeries | All surgical specialties | 20.3% vs. 3.1% (matched, pulmonary complications); 6.5% vs. 0.5% (matched, thromboembolic complications) | 6.5% vs. 0.5% (matched, pulmonary complications) | 16.25 vs. 4.1% (unmatched cohort); 12.2% vs. 4.6% (matched, pulmonary complications) | 12.2% vs. 4.6% (matched, pulmonary complications) | 6.5% vs. 0.5% (matched, thromboembolic complications) |

ACS: acute care surgery, ASA: American society of Anesthesiologists, EIS: emergency abdominal surgery, ICU: intensive care unit, aRR: adjusted relative risk, OR: odds ratio, HBP: hepatobiliary and pancreatic, LT: liver transplantation, SOT: solid-organ transplantation, DM: diabetes mellitus, CKD: chronic kidney disease, BMS: bariatric and metabolic surgery, PSM: propensity score matching.
subsequent large-scale study by the COVIDSurg collaborative involving 140,231 patients from 116 countries found that surgeries performed more than 7 weeks after the diagnosis of SARS-CoV-2 infection was associated with similar mortality risk as that of those without history of SARS-CoV-2 infection [34]. They reported that the 30-day mortality in patients without SARS-CoV-2 infection was 1.5% while in those with SARS-CoV-2 infection was 4.1%, 3.9%, 3.6% and 1.5% in patients having surgery within 0–2 weeks, 3–4 weeks, 5–6 weeks and ≥ 7 weeks, respectively [34].

In an Italian cohort study involving 41 COVID-19 patients matched with 82 non-COVID-19 patients who underwent surgical treatment (general, neurosurgery, orthopedic and vascular surgeries), the surgical complications were significantly higher in the COVID group (Odds ratio 4.98; 95% CI 1.81–16.07) [35]. Moreover, the 30-day mortality rate in the COVID-19 group was also significantly higher (Odds ratio 9.5; 95% CI 1.77–96.53).

Hence, in patients with SARS-CoV-2 infection, non-emergent surgeries should be postponed for 4–7 weeks and non-surgical procedures should be considered in such patients, if feasible.

**Impact of COVID-19 pandemic on the postoperative outcomes of gastrointestinal surgery**

**Emergency surgery**

A retrospective analysis of 100 patients who underwent emergency abdominal surgery in the United Kingdom from March to May 2020 found that the incidence of overall respiratory complications, postoperative COVID-19 infection rate, and the mortality rate was 5%, 3% and 1%, respectively [36]. There was no additional morbidity or mortality associated with COVID-19 infection.

In a Turkish study, 25 patients underwent emergency abdominal surgery from March to April 2020 in the COVID-19 era [37]. None of the patients had preoperative COVID-19, and two had suspected COVID-19. The authors concluded that emergency surgeries could be safely performed in COVID pandemic hospitals if adequate precautions are taken.

Hence, it is recommended that emergency surgeries should be performed during the COVID-19 pandemic. Preoperative SARS-CoV-2 testing should be done prior to surgery. If the patient is not infected, then the COVID-free surgical pathway should be adopted to prevent perioperative SARS-CoV-2 transmission to the patient [38].

**Elective surgery for gastrointestinal cancer**

In the largest multicenter cohort study conducted by COVIDSurg collaborative group, 2073 patients without preoperative COVID from 40 countries who underwent elective colorectal surgery for cancer were included [39]. The postoperative SARS-CoV-2 infection rate was 3.8% cases, the anastomotic leak rate was 4.9%, and the 30-day mortality rate was 1.8%. The independent risk factors for mortality were an anastomotic leak, male sex, postoperative SARS-CoV-2 infection, age > 70 years, and advanced stage of the disease. Compared with the pre-COVID data of 5792 patients from 54 countries published in 2015 and 2017, the anastomotic leak rate and hospital stay were lesser, but the mortality rate was higher. Additionally, the stoma formation rate was higher in the study than in the pre-COVID era (34.2% vs. 27.2%) [39].

A multicenter Spanish study included 259 patients who underwent surgery for colorectal cancer during the COVID-19 pandemic [40]. The major complications, reinterventions, and postoperative COVID-19 related pneumonia were 7.7%, 5.7%, and 1.2% cases, respectively. The median length of hospital stay was 6 days, and the mortality rate was 0.7%.

In an Indian study by Shrikhande et al. on the outcomes of major cancer surgery during the COVID-19 pandemic, 494 patients were included, 84 (17%) patients underwent surgery for gastrointestinal cancer [41]. The authors reported a low incidence of major complications and zero mortality. Also, only six out of 494 patients developed postoperative SARS-CoV-2 infection.

Kapoor et al. reported the outcomes of 314 gastrointestinal surgeries performed during the COVID-19 pandemic (March to July 2020) [14]. Among these, 144 operations were performed for various gastrointestinal cancers. The authors compared the outcomes of these surgeries with that of the previous year during the same time (March to July 2019). Significantly fewer surgeries were being performed during the pandemic, with a higher proportion of cancer surgeries than the previous year (44.9% vs. 23.5%, p < 0.001). However, no significant difference in the incidence of major complications and 30-day mortality were observed in the two time periods [14].

Thus, elective gastrointestinal surgeries can be performed in the COVID-19 pandemic provided the healthcare resources are available and all the safety precautions are maintained to prevent perioperative transmission of SARS-CoV-2 infection among the patients and health care workers.

**Bariatric and metabolic surgery (BMS)**

An international multicenter cohort study (GENEVA) was conducted to determine the outcomes of bariatric surgery in the COVID-19 era [42]. In this study, the 30-day outcomes
of 2001 adult patients (> 18 years) from 127 hospitals in 35 countries who underwent BMS between 1st May and 10th July 2020 were analyzed. The most BMS procedures performed were sleeve gastrectomy [1142 (57%)], Roux-en-Y gastric bypass [557 (28%)], and mini-gastric bypass [215 (11%)]. The 30-day morbidity and mortality rates were 6.8% (n = 138) and 0.05% (n = 1), respectively. The postoperative symptomatic COVID infection rate was 0.5% (n = 10). None of the patients who developed COVID required ICU care and none died [42].

A nationwide French study of more than 4 million obese individuals found that 8286 individuals required admission for COVID-19 between January and May 2020. Among these COVID-19 obese patients, 541 patients had a history of BMS. Interestingly, on logistic regression analysis, the authors found that previous BMS was associated with a significantly reduced risk of mechanical ventilation and mortality [43].

Based on these reports, it can be concluded that BMS can be offered to the obese patients if the healthcare resources are present and appropriate measures are taken to prevent perioperative transmission of SARS-CoV-2 infection. In areas with high incidence of COVID-19, BMS should be resumed once there is reduction in the number of COVID-19-related hospital admissions.

Solid-organ transplantation (SOT)

All the patients undergoing SOT receive immunosuppression, making them prone to develop opportunistic infections. As there was no evidence on the incidence, severity, and impact of SARS-CoV-2 infection in immunocompromised patients at the beginning of the COVID-19 pandemic, SOT was performed only as a life-saving procedure in a limited number of patients. Nevertheless, with the availability of health care resources and a better understanding of COVID-19, several transplant centers have resumed SOT. Most of the transplant centers followed strict perioperative protocol such as preoperative COVID-19 testing of the recipient and donor, COVID free surgical pathway, maintaining isolation in the postoperative period, and COVID-19 testing of the caregivers (Table 2).

A prospective study from Northern Italy included 17 patients who received liver transplantation (LT) between February and April 2020 [44]. Out of these 17 patients, two patients developed COVID-19 infection after LT, and one patient died due to COVID on postoperative day 30. The authors concluded that LT is safe in the COVID-19 pandemic, and LT programs can be continued if the required healthcare resources are available [44].

In a multicenter Indian study involving 31 living donor LT patients (21 adults and 10 pediatric patients) from April to July 2020, one patient developed SARS-CoV-2 infection 46 days after surgery and was recovering at the time of publication [45]. In this patient, mycophenolate mofetil was stopped, and the doses of tacrolimus and steroids were modified. No antivirals were administered due to the risk of hepatitis. None of the donors or transplant team members developed SARS-CoV-2 infection during the study period. The authors emphasized the importance of maintaining strict protocol in preventing the development of COVID-19 in the recipients, donors, or transplant team members [45].

The waitlist mortality rate in the liver transplant candidates is 5% at 6 months, 10.4% at 1 year and 19% at 3 years [46]. However, the mortality in patients with high Model for End-stage Liver Disease (MELD) score > 30 is more than 50% at 3 months [47]. While, the success rate of LT is 90% at 1 year and 80% at 3 years [48]. As the benefit outweighs the risk, considering the ongoing COVID-19 pandemic, most of the transplant societies recommend that the decision to perform LT should be taken based on the local incidence of SARS-CoV-2 infection, availability of resources, severity of the liver disease in the waitlist candidates and the regional/national health policies [49, 50]. In addition, each candidate must be explained the additional risk of SARS-CoV-2 infection and its complications after LT during the counseling process.

Sars-Cov-2 infection in liver transplant recipients

The nationwide study from the Italian registry reported that the cumulative incidence of COVID infection in SOT recipients was 1.02%, which was significantly higher than the non-transplant patients (0.4%) (p < 0.05) [51]. Among 450 SOT recipients with SAR-CoV-2 infection, 89 (19.8%) were LT recipients. The cumulative incidence of SARS-CoV-2 infection was lower in LT recipients compared to kidney and heart recipients. More than 80% of SOT recipients had undergone transplants more than 1 year before the SAR-CoV-2 infection. Out of 450 patients, 123 patients died during the follow-up period. The 30-day and 60-day mortality rates were lower in LT recipients compared to heart and kidney recipients (Table 3) [51].

A study by Kates et al. involving data from more than 50 transplant centers in the United States reported outcomes of 482 SOT recipients with laboratory-confirmed SARS-CoV-2 infection [52]. Out of these, 73 (15.1%) patients had undergone LT. The median age of the included patients was 58 years. The median time post-transplant was 5 years. 376 (78%) patients required hospitalization, including 147 (39%) patients requiring ICU care and 77 (20.5%) patients who died within 1 month after the diagnosis of COVID-19 (Table 3) [52].
Table 2  Perioperative steps to reduce risk of SARS-CoV-2 transmission among the patients and healthcare workers

| Preoperative considerations for all surgical patients [6, 16, 20, 65, 67, 69, 70] | Intraoperative considerations in suspected or confirmed COVID-19 patient [6, 16, 19, 20] | Postoperative considerations in suspected or confirmed COVID-19 patient [6, 19, 20, 69, 70] |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Screening with COVID-19 symptom evaluation and body temperature measurement | Use of regional anesthesia                                                           | Nursing care in dedicated ward, single room or ICU                                         |
| Chest radiogram                                                             | Use of disposable devices                                                              | Use of PPE by all the health care workers                                                  |
| Self-isolation for 14 days                                                   | Use of high level of PPE                                                                | Use of ERAS protocol to facilitate early recovery and minimize hospital stay               |
| Preoperative COVID testing with RAT, RT-PCR or CT chest                     | Donning and doffing of PPE under self-control or direct control of a colleague          | Appropriate steps should be taken to differentiate COVID-related fever from postoperative fever due to surgical complications |
| COVID free surgical pathway                                                 | Use of dedicated OR with laminar air flow, negative pressure and downward evacuation system | Repeat RT-PCR testing if required before discharge                                          |
| Additional informed consent explaining the risk of COVID-19 transmission in COVID-19 negative patient | Stoma formation should be preferred                                                     | Home isolation for 14 days with teleconsultation                                            |
| Additional informed consent explaining the additional risks associated with COVID-19 in suspected or confirmed COVID-19 patient | Minimize gas leaks by using small incisions, balloon/self-sealing trocars                |                                                                                           |
| COVID-19 testing of the caregivers (in patients receiving solid organ transplantation) | Minimize OR staff                                                                     |                                                                                           |
|                                                                             | Use of closed surgical smoke evacuating systems                                         |                                                                                           |
|                                                                             | Minimize use of energy devices to reduce smoke generation                               |                                                                                           |
|                                                                             | Pneumoperitoneum should be evacuated through the port attached to the filtration system before closure, trocar removal, specimen extraction or conversion to open procedure |                                                                                           |
|                                                                             | Use of low CO₂ pressure                                                                 |                                                                                           |

PPE includes use of medical hood, FFP2/FFP3 mask, full-face shield, fluid repellant gown, double disposable gloves and long waterproof leg cover

RAT rapid antigen test, RT-PCR reverse transcriptase-polymerase chain reaction, OR operation room, ICU intensive care unit, PPE personal protective equipment, ERAS enhanced recovery after surgery
Table 3  Studies reporting outcomes of SARS-CoV-2 infection in solid organ transplantation recipients

| Sr. No | Authors | Country | Study period | Study patients | LT recipients | Morbidities | Mortality | Comments |
|--------|---------|---------|--------------|----------------|---------------|-------------|-----------|----------|
| 1      | Trapani S et al. [51] | Italy | 21 February 2020–22 June 2020 | 450 (SOT recipients) | 89 | 72.2% required hospitalization, 17.3% required ICU | 27.3% (overall); 15.7% in LT recipients | CI and mortality rates in LT were lower compared to kidney and heart recipients. The median time from SOT in expired patients was 7.4 years. |
| 2      | Kates OS et al. [52] | USA | 1 March 2020–15 April 2020 | 482 (SOT recipients) | 73 | 78% required hospitalization, 39% required ICU care | 18.7% (overall), 20.5% in LT recipients | The median time from SOT in expired patients was 5 years. |
| 3      | Belli LS et al. (ELITA-ELTR COVID-19 registry) [53] | Europe | 1 March 2020–27 June 2020 | 243 symptomatic adults | 243 | 84% required hospitalization, 19% required ICU care | 20% | Age > 70 years, presence of comorbidities such as DM and CKD were risk factors for mortality |
| 4      | Dumortier J et al. (French SOT COVID-19 registry) [73] | France | 4 March 2020–1 July 2020 | 104 (91 adults and 13 children) | 104 | 64% required hospitalization | 20% (all adults) | Age was the independent risk factor for mortality |
| 5      | Webb GJ et al. [74] | Multicenter | 25 March 2020–26 June 2020 | 151 symptomatic adults | 151 | 82% required hospitalization, 31% required ICU care | 19% | Age, serum creatinine and non-liver cancer were risk factors for mortality |

CI cumulative incidence, ELITA European Liver Transplantation Association, ELTR European Liver Transplant Registry, ICU intensive care unit, SOT solid organ transplantation, LT liver transplantation, NR not reported, USA United States of America
The multicenter study from the European LT Registry (ELTR) is the largest study reporting the outcomes of SARS-CoV-2 infection in 243 adult symptomatic LT patients from 36 centers [53]. They found that 84% of patients required hospitalization, including ICU admission in 19% of cases. About 20% of LT patients died due to COVID-9, with respiratory failure being the primary cause of death. On multivariate analysis, the authors found that age > 70 years, comorbidities such as diabetes mellitus, and chronic kidney disease were independent risk factors for mortality (Table 3) [53].

In a comprehensive review and meta-analysis by Raja et al. including 1500 kidney, 505 liver, and 282 other organ transplant recipients, the pooled incidence of hospital admission, ICU admission, mechanical ventilation, and all-cause mortality was 81%, 29.3%, 25.9%, and 18.6%, respectively [54]. Among the LT recipients, the all-cause mortality rate was 11.8%.

Use of immunosuppression and drugs for COVID infection among LT recipients

In the ELTR study, the authors reported the use of hydroxychloroquine, lopinavir-ritonavir, low molecular weight heparin, high doses of corticosteroids, and tocilizumab for the SARS-CoV-2 infection in LT recipients [53]. Surprisingly, the use of tacrolimus was associated with a significantly reduced risk of mortality in LT recipients with COVID-19 infection [53]. On subgroup analysis, the authors found that patients receiving tacrolimus were younger, had fewer comorbidities, and were less frequently treated with ACE or ARB inhibitors. However, tacrolimus was protective even after taking care of the cofounders. The possible reasons behind the beneficial role of tacrolimus could be direct inhibition of the viral replication and cytokine storm [33]. However, in the multicenter US study by Kates et al., the authors found no association between immunosuppression and 28-day mortality [52].

In the meta-analysis by Raja et al. involving 2772 SOT recipients, the authors reported that immunosuppressive medications, especially antimetabolites, were reduced in 76.2% of patients, and calcineurin inhibitors were reduced in 38.7% of patients [54]. Steroids were seldom reduced. The most commonly used drugs to treat COVID-19 were hydroxychloroquine, azithromycin, IL-6 antagonists such as tocilizumab, protease inhibitors, and high-dose steroids, with the pooled incidence of their use ranging from 14.9 to 59.5% [54].

According to American Association for the Study of Liver Diseases (AASLD) guidelines, the dose of immunosuppressants should not be reduced in LT recipients without COVID-19 [55]. In LT recipients with COVID-19, a reduction in the dose of azathioprine, mycophenolate, and high-dose prednisolone should be considered. The dose of calcineurin inhibitors can be reduced if required but should not be stopped. The use of hydroxychloroquine, azithromycin, and lopinavir-ritonavir to treat COVID-19 is not recommended [55].

Triage of patients for elective surgery during the COVID-19 pandemic

During the pandemic, triage of patients is required to schedule the elective surgery based on the hospital burden of the COVID-19 patients and the available healthcare resources [56]. To facilitate rational, individualized decision-making, a multidisciplinary team that includes oncologists, surgeons, gastroenterologists, radiologists, and other health care providers can be formed to conduct weekly virtual meetings to discuss the pending elective cases [57]. Priority for surgery is given to cancer patients who have completed neoadjuvant therapy, patients with aggressive cancers for which other therapies are not very effective, patients awaiting the second part of the staged procedures, diagnostic procedures, and patients with acute symptoms such as bleeding, bowel obstruction and bowel perforation [57].

Different triage systems have been proposed to guide the clinicians in decision-making [7, 16, 58–60]. Some triage systems are predominantly based on the proportion of the COVID-19-related hospital admissions and availability of hospital resources [58–60]. At the same time, other triage systems are mainly based on the disease and patient factors to determine the urgency of performing the surgical procedure [7, 60–62]. The multidisciplinary team can use these triage systems to propose an individualized treatment plan for the patients waiting elective surgeries during the COVID-19 pandemic.

Regarding LT, elective deceased donor LT should be performed only if both donor and recipient are COVID negative and the recipient is from the same city to avoid air travel [63]. Living donor LT should be carried out only for urgent cases as it exposes the donor to the risk of SARS-CoV-2 infection during hospital admission.

Strategies to reduce perioperative transmission of SARS-CoV-2

In the early period of the COVID-19 pandemic, due to the shortage of personal protective equipment (PPE) and fear of perioperative SARS-CoV-2 transmission to the patients and health care workers, only emergency surgeries were carried in the COVID-19 affected countries. Subsequently, with the availability of PPE, increased healthcare facilities, and a better understanding of the COVID-19 disease, elective surgeries were resumed. However, it is prudent to follow
the strategies recommended by surgical societies based on the available evidence to prevent perioperative COVID-19 transmission [6, 7, 64, 65]. The key recommendations have been summarized in Table 2 [66, 67].

In addition to the general recommendations applicable for all the surgeries, specific precautions need to be followed depending on the type of surgery. For example, in laparoscopy surgeries, extreme care should be taken to prevent SARS-CoV-2 transmission by minimizing aerosol generation, avoiding gas leaks, and appropriate smoke evacuation (Table 2). Surgical smoke is considered to be one of the means of perioperative viral transmission based on the previous reports [21]. The SARS-CoV-2 virus has been found in the peritoneal fluid, bile, ascitic fluid and surgically resected specimens suggesting that the viruses are present in the operative field during the surgery [18, 68]. But, the evidence to support that SARS-CoV-2 infection is transmitted by surgical smoke is lacking [15, 17, 18]. However, due to the theoretical concerns, it is recommended to use personal protective equipments and smoke evacuation devices, minimize aerosol generation, and avoid gas leaks to prevent perioperative SARS-CoV-2 transmission (Table 2) [16, 19, 20].

Regarding LT, the recipient should be tested for SARS-CoV-2 infection by real-time PCR within 24 h of LT [69]. All deceased donors should be preferably tested for COVID-19 by bronchoalveolar lavage. Living donors should be tested 24–72 h before LT. Moreover, self or hospital-based quarantine for 14–21 days before LT should be recommended [70]. If the recipient had active SARS-CoV-2 infection, then LT should be deferred for at least 28 days after symptom resolution and should have two negative RT-PCR tests 24 h apart before LT [69]. The COVID-19-free surgical pathway should be implemented for LT [70]. Post-discharge follow-up hospital visits should be avoided, and online consultation should be encouraged. However, in case of any emergency, the transplant patients should attend the hospital. Treating clinicians should suspect COVID-19 if the recipients develop any COVID-related symptoms such as fever, cough, and breathing difficulty.

Conclusions

Perioperative SARS-CoV-2 infection has an adverse impact on postoperative outcomes. However, patients with COVID-19 should not be denied emergency abdominal surgeries. Elective surgeries should be triaged based on the urgency of performing the surgical procedure, the hospital burden of COVID-19 patients, and the availability of healthcare resources. Routine preoperative screening for SARS-CoV-2 infection should be performed before elective surgeries. Abdominal surgery in COVID patients should be postponed for at least 4 weeks to optimize the postoperative outcomes. All surgeries in COVID-19-negative patients should be performed using the COVID-19-free surgical pathway to prevent perioperative SARS-CoV-2 transmission. LT in COVID-19 pandemic is safe provided it is performed strictly as per the recommended guidelines.

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Declarations

Conflict of interest  The authors have no potential conflict of interest to declare.

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