Surgery in the era of COVID-19: implications for laparoscopy and natural-orifice endoscopic surgery: a narrative review

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Abstract: Controversy exists regarding the use of minimally invasive surgery (MIS) during the corona virus disease 2019 (COVID-19) pandemic. Several surgical societies have issued recommendations regarding precaution measures during MIS, nonetheless these recommendations were conflicting with respect to the use of laparoscopy with little or no inference to natural-orifice endoscopic surgery. A comprehensive literature search was performed to explore the available evidence pertinent to the novel coronavirus 2 (SARS-CoV-2) transmission dynamics in MIS, and benefits of MIS procedures in patients with transmissible viral diseases. According to the current evidence, SARS-CoV-2 has a multi-route transmission, including fecal-oral transmission. Evidence on airborne transmission in the operative setting are however limited. In addition to nasopharyngeal screening, it would seem prudent to perform routine fecal testing for SARS-CoV-2 in patients undergoing positive-pressure transanal minimally invasive procedures. This is particularly relevant to regions with high level of epidemicity. In patients with confirmed SARS-CoV-2 infection, conventional laparoscopic and robotic approaches, and atmospheric transanal surgery with high volume smoke evacuation may be safer alternatives. Considering the high rates of postoperative pulmonary complications and mortality associated with SARS-CoV-2 infection, use of laparoscopy is advised in suspected or confirmed COVID-19 patients who require abdominal surgery, particularly older patients and those with comorbidities. Laparoscopy may decrease the probability of postoperative disease exacerbation, and provide earlier recovery, less morbidity and mortality, and shorter hospital stay with subsequent decreased risk of in-hospital secondary transmission. High index of suspicion in postoperative patients with fever or respiratory symptoms is necessary to timely diagnose COVID-19. Chest computed tomography scan has a higher sensitivity compared to real-time PCR and can potentially be used to assist in the diagnosis, particularly in elderly patients.

Keywords: Corona virus disease 2019 (COVID-19); laparoscopy; fecal to oral transmission; natural-orifice endoscopic surgery

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Introduction

On 30 January 2020, the World Health Organization (WHO) issued a global alert about the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) outbreak, and subsequently named the novel coronavirus pneumonia as Corona Virus Disease 2019 (COVID-19) (1). As of August 1, 2020, a total of 17,396,943 confirmed cases of COVID-19 and 675,060 death cases have been documented globally in 213 countries and territories, with a case fatality rate of 2.3% in China and 1.8–7.2% outside China (2-7).

Virulent infectious diseases may present a life-threatening risk for health care providers during minimally invasive surgery (MIS) procedures, notably laparoscopy and natural-orifice endoscopic surgery. SARS-CoV-2 pandemic brings this concern to the immediate forefront. Several surgical societies have issued recommendations regarding precaution measures during surgery, nonetheless these recommendations were conflicting with respect to the use of laparoscopy, with little or no inference to natural-orifice endoscopic procedures (8-13). Failure to anticipate and address issues related to SARS-CoV-2 infection in MIS procedures may threaten not only surgeons' safety, but colleagues, family and patient safety as well (3). We therefore conducted an up-to-date review of the available evidence pertinent to SARS-CoV-2 transmission dynamics in MIS, and postoperative outcomes and benefits of MIS procedures in patients with transmissible viral diseases with special reference to COVID-19.

We present the following article in accordance with the Narrative Review reporting checklist (available online http://dx.doi.org/10.21037/ales-20-96).

Methods

A comprehensive search of the PubMed, Embase, CINAHL, and Google Scholar databases was carried out to identify relevant articles published before August 1, 2020. Despite being a narrative review, we performed the literature search according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (*Figure 1*) (14). Search terms used were based on the viral agent (e.g., "SARS-CoV-2"), the procedure (e.g., "laparoscopy"), mode of transmission (e.g., "aerosol transmission"), and outcomes (e.g., "complications"). No language restriction was applied. Additionally, the websites of several surgical societies, major journals with specific COVID-19 sections (*NEJM*, *BJS*, *Annals of Surgery*, *The Lancet*, *JAMA Surgery*), the WHO, and the Centers for Disease Control and Prevention (CDC) were also searched. A detailed overview of the literature search is shown in Supplementary file (Appendix 1).

The literature search was conducted by two independent reviewers (HH and GD), and disagreements between reviewers on article inclusion or exclusion were resolved by a third reviewer (AS). Articles were deemed eligible when reporting on SARS-CoV-2 transmission dynamics relevant to MIS procedures, notably laparoscopy, robot-assisted surgery, and transanal endoscopic surgery, and perioperative outcomes and benefits of MIS procedures in patients with transmissible viral diseases undergoing abdominal surgery.

Modes of transmission of SARS-CoV-2 in MIS

Aerosol and fomite transmission

Although the predominant routes of human-to-human transmission of SARS-CoV-2 are thought to be droplet spread related to respiratory secretions and direct contact with oral, nasal, and eye mucous membranes (15), under circumstances relevant to surgeons, aerosol (i.e., droplet nuclei <5 μm) and fomite transmission may occur. Surgical smoke produced by energized dissecting devices is of particular concern in laparoscopic procedures with a proven ability to be a vehicle for transmitting infectious viruses through inhalation (16,17). Presence of viruses such as human immunodeficiency virus (HIV), human papillomavirus (HPV), and hepatitis B virus in surgical smoke has been demonstrated in previous studies (18-20). Among these, HPV was incriminated in nosocomial HPV infections in individuals who were exposed to the smoke (17,21). Recently, the WHO acknowledged aerosol transmission of SARS-CoV-2 especially in closed environments (22). Considering that SARS-CoV-2 has been detected in peritoneal fluid samples from COVID-19 patients (23,24), aerosol transmission of SARS-CoV-2 through surgical smoke remains plausible. Other studies have demonstrated that the particle concentration in smoke produced during laparoscopy was significantly higher compared with open surgery (25). Accumulated smoke during laparoscopy is often released in a high-velocity jet that may be directed toward the surgeon or other operating room personnel. Furthermore, biological material that has deposited onto surfaces can be re-aerosolized by human activities such as walking and cleaning of operating room (26). In addition to inhalation, deposition of large aerosol particles on the personal protective equipments (PPEs), including surgical

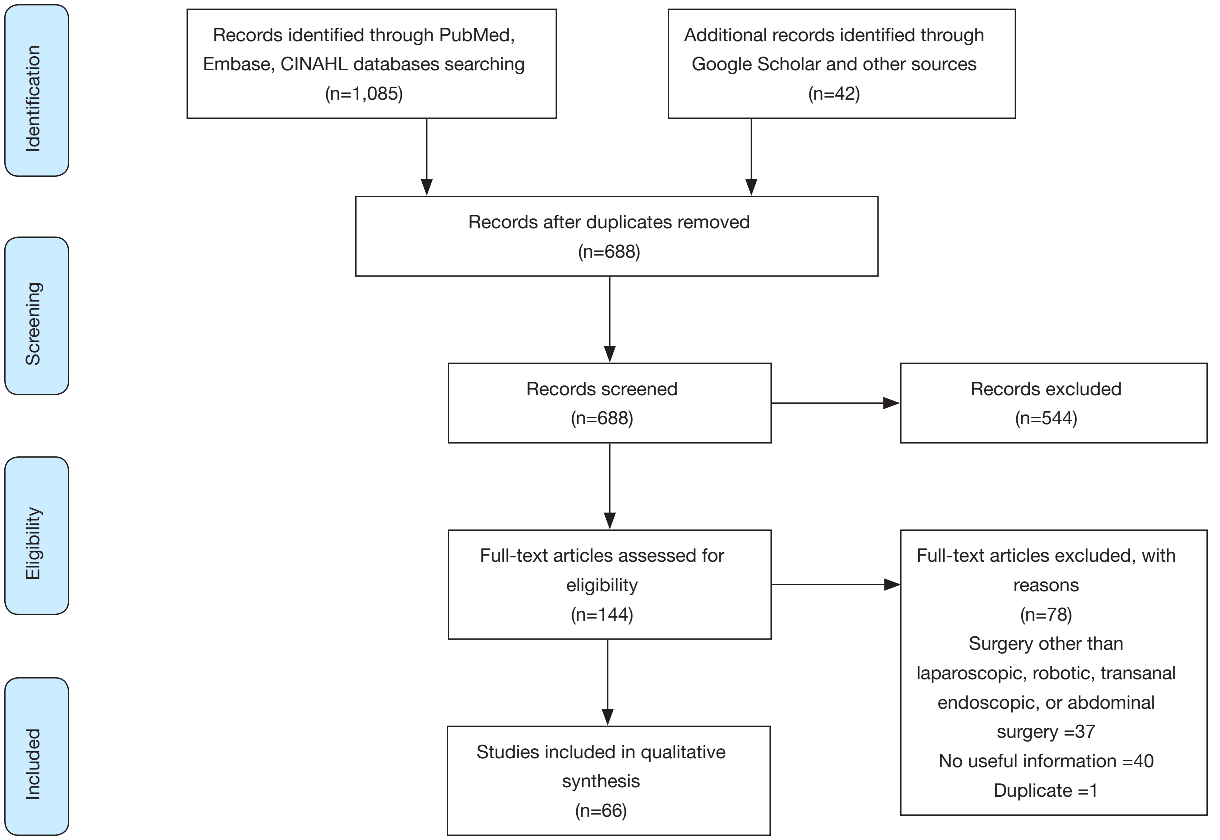

Figure 1 PRISMA flow chart.

masks, may lead to fomite transmission (27). SARS-CoV-2 could remain viable at room temperature on the outer layer of a surgical mask for 7 days (28).

A recent comprehensive review by Tang *et al.* (29), employing Jones and Brosseau criteria (30), has summarized the evidence on airborne transmission of SARS-CoV-2 in the community. It was concluded that the available evidence is strongly indicative of aerosols as one of several routes of COVID-19 transmission (29). On the other hand, several studies have examined the possibility of fomite and airborne transmission of SARS-CoV-2 in healthcare facilities. A study on environmental surveillance of a hospital, designated for treating severe and critical COVID-19 patients, analyzed samples collected from patient's personal belongings and inside and outside the isolation wards after routine cleaning (31). All samples tested negative for SARS-CoV-2 with the exception of the inside of patient's mask (31). Likewise, Cheng *et al.* reported low rates (2.7–7.8%) of environmental contamination by symptomatic and asymptomatic COVID-19 patients; the contamination rate was highest on patient's personal items (32). The same authors also detected a significant correlation between the viral loads of patients' clinical samples and positivity rate of environmental samples (32). On the contrary, Chia and colleagues reported a high rate of surface contamination of 56% in the isolation rooms of patients with non-severe COVID-19 (33). These results were replicated in two other studies evaluating environmental contamination by asymptomatic, mildly ill, or severely ill patients with SARS-CoV-2 infection admitted to intensive care unit (ICU) and general wards. In these studies, viral RNA was detected in 40–76% of patients' personal items, 43–80% of room surface samples, and 17–50% of medical staff's PPEs (34,35). Further, no association was demonstrated between the evidence of environmental contamination and body temperature, indicating that infected individuals may shed viral RNA to the environment without clearly identifiable symptoms (34). In another study by Ong *et al.* (36), collecting surface samples from rooms of 3 COVID-19 patients before and after routine cleaning, 87% of room sites samples collected before cleaning tested positive; all post-cleaning samples were negative. This study revealed extensive environmental contamination by COVID-19 patients, and suggested that appropriate infection control measures could prevent nosocomial infection. Similar findings and conclusions were reported by Razzini *et al.* (37) from their studies on environmental surveillance in a hospital designated for treatment of COVID-19 patients.

Eight studies assessed the risk of airborne transmission of SARS-CoV-2 in clinical settings. Despite using different types of air samplers, 3 of these studies did not detect viral RNA in aerosol samples collected from the isolation rooms of COVID-19 patients (31,32,36). In contrast, Guo *et al.* (35) obtained positive SARS-CoV-2 test results for 35% and 12.5% of aerosol samples collected in the ICU and general wards housing COVID-19 patients. Findings akin to those in the latter study were reported by 2 other studies where 60–70% of room and hallway aerosol samples tested positive for SARS-CoV-2, with a higher airborne concentration of viral RNA in the aerosol samples closest to the patient (33,34). Liu *et al.* (38) measured viral RNA in aerosols in patient, medical staff, and public areas in 2 hospitals designated for treatment of COVID-19 patients. While air samples collected from patient and medical staff areas tested positive, levels of airborne viral RNA in most public areas was undetectable (38). Finally, in a study by Razzini *et al.* (37), only air samples collected from ICU and corridor for COVID-19 patients were positive for SARS-CoV-2 RNA, whereas no viral RNA was found in medical staff areas. Of note, only one of these studies showed evidence of live viral particles in aerosol samples (34), possibly due to the low concentrations of virus in the samples. Furthermore, no data have been reported on the distribution of SARS-CoV-2 in the operating room when COVID-19 patients undergo surgery.

Of interest is an experimental study by van Doremalen *et al.* (39) comparing the aerosol and surface stability of SARS-CoV-2 with SARS-CoV-1, the etiologic agent of severe acute respiratory syndrome (SARS). The results showed SARS-CoV-2 remained viable in aerosols for up to three hours, with stability on surfaces, notably stainless steel and plastic, for at least 72 hours, whereas the aerosol and surface stability of the two viruses were similar (39). In a study by Smither *et al.* (40), a UK variant of SARS-CoV-2 was found to remain viable in aerosols for at least 90 min under experimental conditions (artificial saliva and tissue culture media). Another study suggested SARS-CoV-2 in respirable-sized aerosols could persist and maintain infectivity for up to 16 hours (41). More recently, the findings reported by van Doremalen *et al.* (39) were further confirmed in another experiment showing that SARS-CoV-2 was highly stable in a wide range of pH values (pH 4–11) at room temperature, and remained infectious at 4 ℃ for more than 14 days, and at room temperature for 3–5 days on dry surfaces and 7 days in solution, similar to its phylogenetic relative SARS-CoV-1 (42). Additionally, the virus was found to be susceptible to different types of standard disinfectants (42). All these results indicate that SARS-CoV-2 could survive in aerosols for a relative long time under favorable conditions and potentially spread through aerosols. However, it is perhaps relevant at this juncture to note that the experimental conditions in previous studies may not reflect the clinical setting in which laparoscopic procedures are performed.

Altogether, the available data support fomite transmission of SARS-CoV-2 and highlight the importance of strict adherence to infection-control precautions. In line with the results of a recent review on the risk of airborne transmission of SARS-CoV-2 (43), evidence on aerosol transmission in the operative setting remains limited. Future research should focus on detection of live SARS-CoV-2 in aerosol samples, including surgical smoke, using high efficiency viral aerosol collectors. The correlation between the live viral load in aerosols and patient's clinical symptoms and range also need to be investigated.

Fecal-oral transmission

Similar to other coronaviruses, SARS-CoV-2 has a tropism to the gastrointestinal tract as indicated by reports of diarrhea in some patients and visualization of viral nucleocapsid protein staining in cytoplasm of gastric, duodenal, and rectal epithelium in symptomatic patients with COVID-19 (44), and during the incubation period of the disease (45). SARS-CoV-2 recognizes human angiotensin converting enzyme-2 receptors, the cell-entry receptors for some coronaviruses which are abundantly expressed in small and large intestines (44), more efficiently than the 2003 strain of SARS-CoV-1 (46). This correlates with the efficient spread of the virus among humans.

Several studies have demonstrated the presence of SARS-CoV-2 RNA in 27–83% of anal swabs and stool specimens of COVID-19 patients, including those with no gastrointestinal symptoms (47-52). It was also shown that 33–100% of patients had persistent positive stool viral

RNA despite negative oral or respiratory samples (48-51). These findings were further bolstered by a recent study of 41 patients employing serial sample testing. The results showed fecal samples remained positive for viral RNA for a mean of 28 (±10.7) days after first symptom onset, and for a mean of 11 (±9.2) days longer than respiratory samples, implying that the virus is actively replicating in the patient's gastrointestinal tract after viral clearance in the respiratory tract (53). Rather of concern, some patients had positive fecal samples for 33–42 days continuously after the respiratory samples became negative (53,54). In a similar study by Xu *et al.* (55) evaluating 10 pediatric patients with positive rectal swab viral RNA, 2 patients had positive rectal swabs after clearance with 2 consecutive negative rectal swabs 24 hours apart, suggesting intermittent viral shedding. More importantly, live as well as infectious SARS-CoV-2 was successfully isolated by independent laboratories from stool specimens of COVID-19 patients, including those who did not have diarrhea (52,56,57). In another aspect, the viral load was observed to be consistently higher in toilets used by patients with SARS-CoV-2 infection compared with other contaminated areas (34,38,58), and it was indicated that toilets may promote fecal-derived aerosol transmission if used improperly in hospitals (58). Taken together, the evidence hitherto presented, and the high environmental stability of SARS-CoV-2 shown in previous studies (39,42), lend credence to the notion that SARS-CoV-2 may transmit through fecal-oral route, and viral shedding from the gastrointestinal tract may last long after resolution of clinical symptoms.

The possibility of fecal-oral transmission and the prolonged and intermittent viral shedding in stool in COVID-19 patients as well as asymptomatic carriers (54,59,60) may have important implications for patients undergoing natural-orifice transanal endoscopic procedures performed under positive pressure, which are considered aerosol generating procedures. Presently, fecal sample testing for SARS-CoV-2 is not part of the routine investigations in this patient group. Those patients may be SARS-CoV-2 carriers or have mild symptoms not meeting the definition for case finding (2). Further, according to the current CDC guidance, diagnostic testing for SARS-CoV-2 infection is performed using upper or lower respiratory, and not fecal samples (61). Thus, we believe that performing positive-pressure transanal endoscopic procedures may carry a potential risk of short-range (within 1 m distance) airborne transmission to the surgical team from exposure to fecal and body fluid aerosols.

Considerations for surgical patients with transmissible viral diseases

Infection of with SARS-CoV-1, SARS-CoV-2, and HIV poses a considerable challenge in management of surgical patients in the perioperative period. For infection with SARS-CoV-1 and SARS-CoV-2, diagnosis in the postoperative period can be difficult and requires high index of clinical suspicion. Although those patients present with symptoms similar to common SARS and COVID-19, these symptoms are often attributed to surgical infections or other postoperative complications, leading to delayed diagnosis and treatment with particularly poor outcomes in elderly patients and those with comorbidities or undergoing complex procedures (62-64). It was reported that the postoperative mortality rates in patients with SARS and COVID-19, including those undergoing abdominal procedures, were 33% and 7–67%, respectively; in most cases, mortalities were due to respiratory complications and sepsis (62-67). These complications could be ascribed in large part to impaired cell-mediated immunity associated with the acute phase of the underlying viral disease (64,68). Likewise, nearly 11–35% of HIV/AIDS patients develop complications after abdominal surgery, mostly chest problems and sepsis, with mortality rates of 3–22% (69-71). Of note, the use of laparoscopy in recent years has significantly reduced the postoperative hospital stay, morbidity, and mortality in this patient group, particularly in emergency settings (72).

Even though no data available regarding the safety and outcomes of open versus laparoscopic abdominal procedures in COVID-19 patients, the use of laparoscopy has been advocated in these patients (9,12). Borrowing from the HIV/AIDS example, employing laparoscopic approach in COVID-19 patients, including who are diagnosed preoperatively, may provide earlier recovery, less morbidity and mortality, and shorter hospital stay with subsequent decreased risk to patients and surgical team of virus exposure. Studies have indicated that artificial pneumoperitoneum was well tolerated by patients with poor preoperative pulmonary function, including those undergoing complex upper abdominal procedures (73,74), and despite the prolonged operative duration, laparoscopy was associated with lower postoperative pulmonary complications compared with open surgery (74). Moreover, the use of neuraxial anesthesia or general anesthesia with intraoperative protective lung ventilation (i.e., low tidal volume with positive endexpiratory pressure) may further reduce the incidence of desaturation events and pulmonary complications after laparoscopic surgery (75,76). Laparoscopy may also confer the advantage of less perioperative immunosuppression compared with open surgery (77), and hence decreases the probability of postoperative COVID-19 exacerbation especially after emergency surgery (64,78). This is particularly relevant considering that most surgical patients with COVID-19 are asymptomatic or have non-specific symptoms prior to surgery and are diagnosed in the immediate postoperative period (73). Many of those patients likely have preoperative subclinical infection.

In elective setting, notably oncosurgery, robotic approach may be a valuable option to reduce the number of potential interactions between surgical team and patient and risk of infection, with perioperative outcomes equivalent to laparoscopic surgery (79).

Suggested practical measures for MIS during COVID-19 pandemic

Recommendations issued by several surgical societies (8-13) as well as experts (80) regarding infection-control measures relevant to MIS are summarized in *Table 1*. Additionally, based on the available evidence, we suggest the following:

❖ Generally, in both emergency and elective settings, the surgical approach associated with the least operation time, hospital stay, and risk of infection for both patients and surgical team should be used. This should be adapted to the available resources and local level of epidemicity of SARS-CoV-2.

❖ Use of laparoscopy is advised in suspected or confirmed COVID-19 patients who require abdominal surgery, particularly older patients and those with comorbidities. A variety of commercially available ultrafiltration devices can be used during laparoscopic procedures (*Table 2*). In addition, a low-cost and effective filtration system has recently been devised to be used in low-resource settings (81).

❖ Routine preoperative fecal PCR testing, in addition to nasopharyngeal screening, for SARS-CoV-2 in patients undergoing transanal/transrectal natural-orifice transluminal or endoluminal surgery under positive pressure. This includes transanal endoscopic microsurgery (TEM), transanal minimally invasive surgery (TAMIS), and transanal/transrectal NOTES procedures such as transanal total mesorectal resection (TaTME) and transrectal sigmoid resection. Rapid antigen testing is less costly and may be a consideration in low-resource settings (82).

❖ In patients with suspected/confirmed SARS-CoV-2 infection, conventional laparoscopic and robotic approaches, atmospheric transanal surgery with high volume smoke evacuation, and temporization with chemotherapy and/or radiotherapy may be safer alternatives to transanal/transrectal endoscopic surgery.

❖ Different types of thermal energy devices are used during transanal endoscopic procedures for dissection and hemostasis, most commonly electrocautery and ultrasonic scalpels. Although the latter were shown to be associated with reduced operative time compared to standard electrocautery (83), they generate lower temperature vapor with larger particles (0.35–6.5 µm) which is associated with a higher risk of carrying infectious particles (84). Therefore, it would seem prudent to minimize the use of ultrasonic scalpels in these procedures during the pandemic if possible.

❖ Use of appropriate PPE cannot be overemphasized, particularly in patients with suspected/confirmed SARS-CoV-2 infection. The minimum standard of PPE when caring for a patient with suspected/confirmed COVID-19 infection is fluid-resistant gown, eye protection (side shields, goggles, or full-face shield), fit-tested N95 respirator, hair covers or hoods, and long sleeved gloves if available (85). At this time, there is no definitive evidence that powered air-purifying respirators reduce the likelihood of viral transmission in the setting of potential airborne spread. In low-resource settings, reduced PPE may be used which includes scrubs, hair covering, long gown, boots, face shield or goggles, reused respirator, or surgical mask (82).

❖ High index of suspicion in postoperative patients with fever and/or respiratory symptoms is necessary to timely diagnose COVID-19. Chest computed tomography (CT) scan has a higher sensitivity compared with real-time PCR (94% *vs.* 89%), and can potentially be used to assist in the diagnosis of COVID-19, particularly in elderly patients (86).

Conclusions

As the novel coronavirus (SARS-CoV-2) continues to

Table 1 A summary of considerations and practical recommendations relevant to MIS

	Recommendations
General measures	• Preoperative screening for COVID-19 of all surgical patients whenever available and practical (9,11-13,70) • Appropriate use of PPE, hand hygiene, and use of effective disinfectant solutions should be strictly employed (8,9,11-13) • Proper OR filtration and ventilation, and use of negative pressure rooms if available (8-10,13) • Minimizing number of personnel during and after surgery (8,9,11,12)
Laparoscopy	• No consensus regarding use of laparoscopy • ACS: consider avoiding laparoscopy (8) • SAGES and EAES: laparoscopy should be strongly considered in COVID-19 patients (9) • IGAG (*): consider laparoscopy only of clinical benefit to the patient substantially exceeds the risk of potential viral transmission (11) • AEC: consider laparoscopy in COVID-19 patients (12) • JSS: no evidence to support open surgery over laparoscopy (13)
Hand-assisted laparoscopy	• Avoid hand-assisted laparoscopy as it is associated with uncontrolled surgical smoke emissions (10)
Positioning in laparoscopy	• Avoid prolonged Trendelenburg position in COVID-19 patients which may compromise the cardiopulmonary function (12,13,70)
Surgical smoke	• Use the smallest possible incision for port insertion to avoid periportal leakage (9,12) • Avoid venting of ports after placement (10) • Keep CO_2 insufflation pressure to the minimum (9,12,13,70) • Avoid unnecessary ablation of tissues to minimize the production of surgical smoke (70) • Electrosurgery units should be set to the lowest possible settings (9) • Minimize use of ultrasonic devices as they produces low-temperature bioaerosols with a high chance of carrying viable viral particles (9,12,70) • Evacuation of pneumoperitoneum should be performed before closure, trocar removal, specimen extraction, or conversion to open surgery (9-13) • Safe evacuation of pneumoperitoneum using ultra-filtration devices to capture all CO_2 gas and particulate matter, including viruses (8-10) • Avoid use of surgical drains unless necessary (10)

*, Joint statement by the ASGBI, ACGBI, AUGIS, RCS(Edin), RCSI, RCS(Eng), and RCSPG. PPE, personal protective equipments; OR, operation room; ACS, American College of Surgeons; SAGES, Society of American Gastrointestinal and Endoscopic Surgeons; EAES, European Association for Endoscopic Surgery; IGSG, Intercollegiate General Surgery Guidance; AEC, Spanish Society of Surgery; JSS, Japanese Surgical Society.

impact the healthcare systems globally, many interventions will be needed to minimize the risk of nosocomial infection and optimize patient care. The virus appears to have a multi-route transmission, including fecal-oral transmission. Routine preoperative fecal testing for SARS-CoV-2 is therefore strongly recommended in all patients undergoing positive-pressure transanal minimally invasive procedures. Notwithstanding the limited data on surgical outcomes of COVID-19 patients, laparoscopy may benefit these patients and lessen risks to the operative team if basic infection-control tenets are observed. Diagnosis of COVID-19 in the postoperative period requires high index of suspicion, and chest CT scan can potentially be used to assist in the diagnosis.

Table 2 A summary of commercially available smoke evacuation systems for laparoscopic procedures

Manufacturer	Product	ULPA	Micron filtration	Active or passive evacuation
ConMed	Airseal®; Buffalo filter®	Yes	0.01	Active
CooperSurgical	SeeClear®; Plume-Away	Yes	0.1	Passive
Ethicon	Megadyne™; MegaVac Plus	Yes	0.1	Active
IC Medical	CrystalVision 450-D	Yes	0.1	Active
Medtronic	RapidVac™	Yes	0.1–0.2	Active
Stryker	Pneumoclear™; PureView™	Yes	0.051–0.1	Active
Northgate	Nebulae™ I	Yes	0.12	Active
Symmetry surgical	Smoke Shark II	Yes	0.1–0.2	Active
Olympus	UHI-4	No	NA	Active
Karl Storz	S-Pilot	No	0.027	Active

Reproduced from a document published by the Society of Gastrointestinal and Endoscopic Surgeons (10). ULPA, ultralow particulate air.

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Footnote

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Supplementary

Literature search

Search strategy for PubMed (Medline) (1946 to August 1, 2020)
585 results:

#1	(COVID-19[Title] OR SARS-CoV-2[Title] OR 2019-nCoV[Title])	31,907
#2	(viral transmissible[Title/Abstract] OR viral infectious[Title/Abstract])	532
#3	#1 OR #2	32,433
#4	(laparoscop*[Title/Abstract] OR minimally invasive[Title/Abstract] OR robot*[Title/Abstract] OR Trans-anal endoscop*[Title/Abstract] OR Transanal endoscop*[Title/Abstract] OR natural orifice endoscop*[Title/Abstract])	216,573
#5	(surgery[Title] OR surgical[Title] OR perioperative[Title] OR preoperative[Title] OR postoperative[Title])	731,225
#6	(fecal-oral OR oral-fecal OR oro-fecal OR faecal-oral OR oral-faecal OR oro-faecal OR fomite* OR Aerosol OR airborne)	79,078
#7	(transmission)	538,757
#8	#6 AND #7	6,293
#9	(treatment[Title] OR management[Title] OR outcome*[Title] OR complication*[Title])	1,904,385
#10	#3 AND #4 AND #8	27
#11	#1 AND #8	465
#12	#3 AND #5 AND #9	129
#13	#10 OR #11 OR #12	585

Search strategy for EMBASE (1980 to August 1, 2020)
423 results:

#1	(COVID-19 OR SARS-CoV-2 OR 2019-nCoV).ti	31,873
#2	(viral transmissible OR viral infectious).ti,ab	660
#3	#1 OR #2	32,526
#4	(laparoscop* OR minimally invasive OR robot* OR Trans-anal endoscop* OR Transanal endoscop* OR natural orifice endoscop*).ti,ab	329,960
#5	(surgery OR surgical OR perioperative OR preoperative OR postoperative).ti	810,275
#6	(fecal-oral OR oral-fecal OR oro-fecal OR faecal-oral OR oral-faecal OR oro-faecal OR fomite* OR Aerosol OR airborne).ti,ab	71,631
#7	(transmission).ti,ab	403,128
#8	#6 AND #7	4,786
#9	(treatment OR management OR outcome* OR complication*).ti	2,390,334
#10	#3 AND #4 AND #8	9
#11	#1 AND #8	296
#12	#3 AND #5 AND #9	131
#13	#10 OR #11 OR #12	423

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Search strategy for the Cumulative Index of Nursing and Allied Health Literature (CINAHL)
77 results:

#1	(COVID-19 OR SARS-CoV-2 OR 2019-nCoV).ti	7,767
#2	(viral transmissible OR viral infectious).ti,ab	1,996
#3	#1 OR #2	9,733
#4	(laparoscop* OR minimally invasive OR robot* OR Trans-anal endoscop* OR Transanal endoscop* OR natural orifice endoscop*).ti,ab	50,953
#5	(surgery OR surgical OR perioperative OR preoperative OR postoperative).ti	164,289
#6	(fecal-oral OR oral-fecal OR oro-fecal OR faecal-oral OR oral-faecal OR oro-faecal OR fomite* OR Aerosol OR airborne).ti,ab,au	5,490
#7	(transmission).ti,ab,au	37,567
#8	#6 AND #7	710
#9	(treatment OR management OR outcome* OR complication*).ti	556,561
#10	#3 AND #4 AND #8	2
#11	#1 AND #8	66
#12	#3 AND #5 AND #9	13
#13	#10 OR #11 OR #12	77

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