

# Current Evidence for Minimally Invasive Surgery During the COVID-19 Pandemic and Risk Mitigation Strategies

## A Narrative Review

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**Objective:** Our objective was to review the literature surrounding the risks of viral transmission during laparoscopic surgery and propose mitigation measures to address these risks.

**Summary Background Data:** The SARS-CoV-2 pandemic has caused surgeons the world over to re-evaluate their approach to surgical procedures given concerns over the risk of aerosolization of viral particles and exposure of operating room staff to infection. International society guidelines advise against the use of laparoscopy; however, the evidence on this topic is scant and recommendations are based on the perceived most cautious course of action.

**Methods:** We conducted a narrative review of the existing literature surrounding the risks of viral transmission during laparoscopic surgery and balance these risks against the benefits of minimally invasive approaches. We also propose mitigation measures to address these risks that we have adopted in our institution.

**Results and Conclusion:** While it is currently assumed that open surgery minimizes operating room staff exposure to the virus, our findings reveal that this may not be the case. A well-informed, evidence-based opinion is critical when making decisions regarding which operative approach to pursue, for the safety and well-being of the patient, the operating room staff, and the healthcare system at large. Minimally invasive surgical approaches offer significant advantages with respect to both patient care, and the mitigation of the risk of viral transmission during surgery, provided the appropriate equipment and expertise are present.

**Keywords:** aerosolization, COVID-19, laparoscopy, minimally invasive surgery, pandemic

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The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has redefined the scope of the surgeon's practice, with nononcologic elective operations almost universally postponed and a heightened sense of caution around even routine procedures.

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Surgeons are being asked to adapt their practice of medicine based on scant evidence. One of the most significant changes has been the widespread concern around performing minimally invasive (laparoscopic) procedures, and in some cases the opposition of the technique.<sup>1,2</sup> This is due to the perceived risks of aerosolization of intraperitoneal viral particles and the added exposure risk to the operating room staff. One of the first published manuscripts to describe this dilemma combined the Italian and Chinese experience for recommendations regarding the use of minimally invasive surgery during the COVID-19 pandemic.<sup>3</sup> The article provides strong foundations in the discussion around the use of minimally invasive techniques during the pandemic, addressing perioperative, intraoperative, and postoperative principles. We sought to further investigate these concerns and claims of aerosolization, evaluating the evidence for and against this notion. Furthermore, we provide the evidence in the context of an institutional protocol to mitigate these risks whereas continuing to capitalize on the advantages provided by minimally invasive surgery.

Ultimately, this narrative review represents a summary of the evidence around various aspects of laparoscopic and open techniques that are important to consider when deciding on one's approach to various clinical presentations during a pandemic such as COVID-19. It is up to each institution's individual surgical staff, operating room team and surgical administrators to decide on whether to proceed with this technique of surgery, based on appropriate indications and patient factors.

### GASTROINTESTINAL (GI) DISTRIBUTION OF THE SARS-COV-2 VIRUS

SARS-CoV-2 is an RNA based, lipid enveloped virus of the coronaviridae family that resulted in the World Health Organization declaration of the worldwide coronavirus disease 2019 (COVID-19) pandemic in March 2020. The viral size was found to vary between 0.06 and 0.14  $\mu\text{m}$ .<sup>4</sup> Although the SARS-CoV-2 pandemic is primarily characterized by its effect on the respiratory system, the virus can be found in many other tissues. The characteristic S surface protein of this virus seems to attach to the angiotensin converting enzyme-II (ACE2) receptors. As such, there has also been a surge of research into where the ACE2 receptors are located throughout the body.<sup>5</sup> Much of the data published thus far relies on multiple samples from a relatively limited number of actual patients, so results must be interpreted with some caution.

It has been well established that SARS-CoV-2 RNA can be detected using nasopharyngeal and sputum sampling through reverse-transcription polymerase chain reaction (RT-PCR).<sup>6–9</sup> Outside of the lung and oropharynx, the ACE2 receptor can be found in colonocytes, gastric, duodenal, jejunal, ileal, and rectal endothelial cells, and in smooth muscle cells of the muscularis mucosae, muscularis propria, and vasculature of the GI tract.<sup>10,11</sup> More

recently, it has become clear that viral RNA can also be found in the stool of patients with COVID-19.<sup>6–9,12,13</sup> In fact, some studies purport that the sensitivity of stool testing approaches that of nasopharyngeal sampling.<sup>7</sup> Stool testing can also remain positive for up to 5 weeks beyond normalization of nasopharyngeal and respiratory testing.<sup>8,12</sup> There seems to be a “lag period” between the onset of symptoms and respiratory positivity, and subsequent stool positivity.<sup>8</sup> The clinical significance of the presence of viral RNA in the stool is not yet known. It seems that the virus actively replicates in the GI tract (rather than simply undergoing an extended “wash-out” time); however, culture studies have not found viable, infectious viral particles in stool.<sup>6,8</sup> Despite this fact, there has been speculation that a fecal-oral route of transmission is viable, mainly based on previous experiences with the SARS and middle eastern respiratory syndrome viruses, members of the coronavirus family.<sup>8,14</sup>

Apart from the sputum and stool, SARS-CoV-2 has been isolated from few other bodily fluids. Multiple studies have been unable to detect viral RNA in urine or blood, except for in relatively rare clinically severe cases wherein viral RNA can be detected in serum.<sup>6,9,15</sup> Many COVID-19 patients are found to have elevated liver enzymes, leading to the suspicion of hepatic involvement; however, there is little evidence that such liver injury is a direct effect of the virus.<sup>16,17</sup> Instead, it is thought that liver injury results from a systemic response to the virus or from the myriad drugs currently used in an attempt to treat with 1 study showing that liver failure was no more common in COVID-19 patients than it was in similarly severe cases of community-acquired pneumonia.<sup>16</sup> Notably, ACE2 is not found in liver hepatocytes, Kupffer cells, or in the liver endothelium, but is found to have low level expression in hepatic cholangiocytes.<sup>10,11,18</sup> No studies could be found investigating the presence of SARS-CoV-2 in the bile or abdomen in general.

Based on current evidence, SARS-CoV-2 RNA is present throughout the GI tract, though it is unclear if fecal-oral transmission is possible. This needs to be a point of consideration when managing patients with a perforated viscus and COVID-19 to ensure appropriate precautions are employed, including complete personal protective equipment (PPE) for healthcare providers, patient isolation, and negative pressure rooms where available.

### MINIMIZING RESOURCE UTILIZATION BY ENHANCING RECOVERY AND TIME TO DISCHARGE

A number of factors are considered with surgical planning during a pandemic. Access to operating rooms, personnel exposure, and enhancing the recovery of patients by minimizing complications and length of stay are all taken into account. Understanding the benefits of minimally invasive techniques on the above will help in the risk-benefit discussion around laparoscopic surgery.

Several general surgical procedures are known to be more effectively addressed with minimally invasive techniques; we chose 3 commonly performed procedures that seem to benefit most from a laparoscopic approach to briefly review the pandemic-specific considerations.<sup>19</sup>

#### Appendectomy for Acute Appendicitis

Numerous randomized controlled trials (RCT) have been synthesized in systematic reviews and meta-analyses (SRMA), all of which advocate for laparoscopic over open appendectomy. Two SRMAs of 39 and 64 RCTs demonstrated that patients undergoing laparoscopic appendectomy for acute appendicitis had fewer wound infections, earlier oral intake, shorter length of stay and return to normal activity, required less analgesia (parenteral and oral), and had a better cosmetic result when compared with an open approach. There was no difference in any postoperative complications between groups.<sup>20,21</sup> This benefit also translates to complicated or perforated

appendicitis. SRMAs of RCTs and cohort studies have shown a 72% reduced risk of surgical site infections, and absolute reductions in length of stay by 2.5–3.5 days, and reductions in time to oral nutrition by up to 1 day with laparoscopy. There is some heterogeneity as to the differential lengths of surgery with at most a 14-minute increased duration with laparoscopy. No differences in the risk of postoperative abscess formation were found, a factor that would lead to readmission and use of healthcare resources.<sup>22,23</sup> Similarly, a SRMA of 12 studies (total n = 339,438) compared laparoscopic to open appendectomy in elderly patients (>65 years), finding a 67% reduction in mortality, a 35% reduction in overall complication rate, a 73% reduction in wound infection rate, and a length of stay reduction of 2.7 days in patients undergoing laparoscopic appendectomy.<sup>24</sup>

#### Cholecystectomy for Acute Cholecystitis

Laparoscopy has become the standard approach for cholecystectomy, with similar volumes of research supporting the movement towards laparoscopy. The decreased exposure of trainees to open cholecystectomy over the past 2 decades has resulted in a decreased level of comfort with this technique.<sup>25</sup> A SRMA of 10 RCTs incorporating 1248 patients compared laparoscopic to open cholecystectomy and found a ~50% decrease in overall complications with a laparoscopic cholecystectomy when compared with open, with an 80% decrease in mortality and a decrease in length of stay by almost 5 days. No difference in bile leak, blood loss, or operative duration was found.<sup>26</sup> For acute cholecystitis, laparoscopic surgery offers numerous clinically important advantages, similarly when needing to perform a subtotal cholecystectomy due to intraoperative difficulties.<sup>27</sup> The authors are not recommending against an open technique, but rather that given the current exposures in training and the enhanced visualization with laparoscopy, a difficult cholecystectomy being performed laparoscopically is not necessarily going to be made easier with an open technique; in fact, one would be concerned about the lack of familiarity with various aspects resulting in increased morbidity.<sup>28</sup>

#### Perforated Viscous and Obstructing Cancer

The technique of managing a perforated viscus in emergency general surgery is multifactorial, dependent on factors such as the patient’s hemodynamic stability, comorbidities, and ultimately the technical expertise of the surgeon and operating team. A number of studies have compared laparoscopic to open emergency surgical approaches for perforated viscous of multiple etiologies. A retrospective cohort study matched patients undergoing laparoscopic to open sigmoid resection for perforated diverticulitis, finding a 2-day shorter length of stay, a 22% reduction in complication rate, and a greater stoma reversal rate in laparoscopic cases compared with matched open counterparts. Laparoscopic resection extended operative duration by ~30 minutes, but no differences were found in need for re-intervention or mortality.<sup>29</sup>

A SRMA of 11 RCTs comparing laparoscopic to open colectomy for any emergency indication found that laparoscopic surgery resulted in an increased operative duration (mean different 37 minutes), but a 56% lower morbidity, 2.8-day reduction in length of stay, in addition to decreased times to GI function and oral intake; it found no difference in intraoperative blood loss, reoperation rate, infection, abscess, ileus, or mortality. A subgroup analysis of cancer patients within those groups found no difference between R0 resection rates or lymph node yield.<sup>30</sup>

A common theme identified above is a marginal increase in operative duration of some procedures by 15–45 minutes that are found to afford significant improvements in morbidity, recovery, and length of stay in hospital, minimizing the patient’s exposure to the institution. Patients post-cholecystectomy and appendectomy can often be discharged directly from the recovery unit, whereas patients with more

extensive procedures may need a short period of observation. Ultimately, the decision needs to take into account patient-centered characteristics, but also surgeon and institution-specific details to ensure a safe provision of care with the chosen surgical approach.

### RISK OF TRANSMISSION AND MITIGATION STRATEGIES

Certain surgical procedures, both laparoscopic and open approach, have been labeled as aerosol generating medical procedures, which are those which result in a production of airborne particles that may remain suspended in the air or travel over a distance.<sup>31</sup> During surgery, aerosolization can result from dissection with electro-surgical instruments, as the heat of such devices results in a plume of surgical smoke. Once the boiling point is reached, cell membranes rupture, generating a plume composed of 5% organic vapors, particulate matter, and cellular debris, and 95% water vapor.<sup>32,33</sup> The size and composition of the particles seems to be related to the electro-surgical device used, producing surgical smoke that has been shown to have a toxicity similar to or greater than cigarette smoke.<sup>34</sup> Previous studies have demonstrated that electro-surgical devices can produce aerosolized bacteria and viruses including human immunodeficiency virus, human papillomavirus, and hepatitis virus with a number of studies demonstrating a risk of oral papillomatosis due to occupational exposure.<sup>35–38</sup> Such devices may also increase the risk of infectious transmission of pathogens like SARS-CoV-2.

The aerosolization risk in laparoscopy is still unclear but often related to reports of laparoscopic port site metastases during earlier experiences, hypothesized to be related to the state of pneumoperitoneum with associated pressure-related air currents in the abdomen.<sup>39</sup> Although the risk of viral infection of the surgeon is well-documented in open surgery, no such literature exists in laparoscopic surgery. However, studies comparing the quantity and quality of surgical smoke produced by various instruments found that the main determinant of aerosolization was the instrument used, supporting the notion that the surgical plumes are produced in both laparoscopic and open surgery.<sup>40</sup> Conversely, analyses of the contents of pneumoperitoneum identified sevoflurane as a constituent, suggesting a pathway by which pulmonary contents can enter the

abdomen during laparoscopic surgery; however, this article also suggests that the concentrations of such materials are low in the well ventilated operating room environment but also, one would hypothesize that these waste products from the respiratory tract are likely to also be produced during open procedures as well.<sup>41</sup>

In general, a number of strategies are employed in operating rooms to mitigate these risks including negative-pressure ventilation (preventing cross-contamination between rooms), minimizing time and exposure during intubation, using surgical masks, and smoke evacuation systems.<sup>42–45</sup> Some concern has been raised regarding surgical and N95 masks and the ability to prevent the inhalation of particles in surgical smoke, given that N95 masks filter particles larger than 0.3  $\mu\text{m}$  whereas generated particle size ranges from 0.07 to 0.42  $\mu\text{m}$  for electrocautery, 0.35 to 6.5  $\mu\text{m}$  for ultrasonic scalpels, and 0.06 to 0.14  $\mu\text{m}$  for the SARS-CoV-2 virus particle itself.<sup>4,46</sup>

### Creation of a Closed Circuit and Viral Filter Properties

In open surgery, smoke evacuation systems are used to control surgical plume, typically composed of suction devices attached to the electro-surgical source.<sup>32,39,40</sup> Several recent studies on smoke evacuation devices found that the pencil like “smoke evacuator” decreased the average smoke level by between 44.1% and 99%.<sup>47,48</sup> What is evident is that the efficacy is variable and depends on factors including evacuator flow rate, angulation of the surgical device from the skin, distance between the evacuator nozzle and the surgical site, and direction and speed of external air flow in relation to nozzle flow.<sup>49</sup>

Laparoscopic procedures have the ability to create a more regulated closed environment that allows all inflow and outflow of air to be controlled through the well-defined points of access, the trocars. Although the article by Zheng et al refers to definitive increased risks with laparoscopy, we speculate that laparoscopic procedures may actually reduce the risk of viral transmission to operating room staff via surgical smoke when compared to open procedures.<sup>3</sup> This is hypothesized due to the closed and regulated abdominal environment, which can act as a barrier and containment entity (Fig. 1).

Smoke evacuators used according to the association of peri-operative room nurses standards are expected to use ultra low

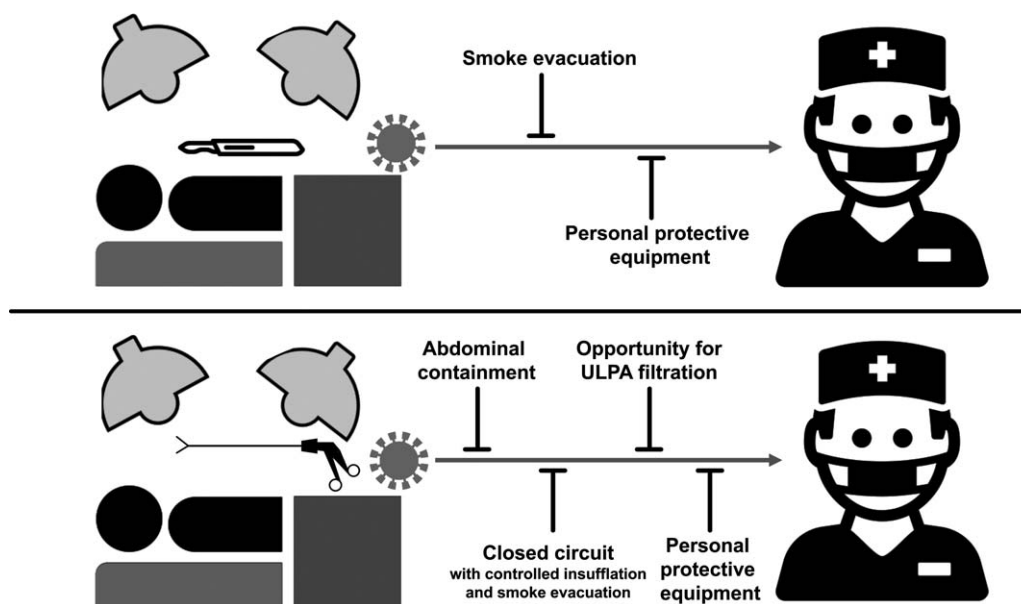


FIGURE 1. Comparative mitigation strategies in open and laparoscopic approaches.

particulate air (ULPA) filters, which are quoted to filter 99.999% of particles greater than 0.1  $\mu\text{m}$ . Practically speaking, such machines filter evacuated air, the effluent of which is ejected into the operating room environment. As such, if the filter does not address the appropriate particle size, there is potential for exposure of the entire operating room staff. Various societies such as the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) have published guidelines for the use of smoke and gas evacuation during laparoscopic and open procedures.<sup>50</sup> Various proposals have been made for low cost options for smoke evacuation, attaching commonly found ULPA filters used as part of anesthetic tubing to a standard laparoscopic port.<sup>51</sup>

Some of the principles of smoke evacuation during laparoscopy are discussed in the article by Zheng and colleagues; however, there is a need to discuss some of the SARS-Cov-2-specific principles to ensure the appropriate precautions are taken.<sup>3</sup> A number of smoke evacuation devices are available which can also be seen in the SAGES reference document.<sup>50</sup> Regarding SARS-Cov-2, reports differ with respect to viral particle size, ranging from 0.06 to 0.14  $\mu\text{m}$ . Ultimately, given that we do not know the infectivity of the various particle sizes, it is prudent to be cautious with even the smallest particle sizes. The Stryker Pneumoclear insufflator utilizes an ULPA filter that was recently assessed and found to effectively filter particles at the 0.051  $\mu\text{m}$  size. Similarly, the ConMed AirSeal system utilizes a 0.01  $\mu\text{m}$  ULPA filter. The authors feel it is extremely important for the end-user to be aware of the recommendations with the AirSeal device pertaining to the bifurcated Smoke Evacuation tubing (SEM-EVAC) as it allows the surgical team to use a controlled inflow and smoke evacuation tube set that connect to the filter listed above with a valved trocar so as to maintain a closed circuit in the intra-abdominal environment. Other companies such as the Alesi Surgical Ultravision report filtration of particles as small as 7 nm. We would recommend surgeons research their individual hospital resources to ensure safety based on the above specifications.

### Insufflational Pressures and Flow: Managing the Pressure Gradient

A pressure gradient is created when 2 separate areas have differential pressures. During laparoscopic surgery, the intraperitoneal

environmental pressure is defined using the insufflator. In North American operating rooms, this is often set at 15 mm Hg whereas other locations around the world often use a pressure of 12 mm Hg; lower pressures (as low as 8 mm Hg) are being explored in combination with deep neuromuscular blockade. Early in vivo studies have suggested that higher pressure environments and longer procedure times could contribute to an increase in rates of aerosolization, as measured by the extent to which cellular debris was found to spread through the abdominal cavity. These models have identified aerosolization to be related to the length of the procedure, the manipulation of the various cellular debris, and general ventilatory patterns in the abdomen, but more recently this has also been related to higher flow rates in the abdomen.<sup>52,53</sup> Increased insufflation pressures are also associated with increased instrument contamination and increased port-site recurrence in cancer operations.<sup>54</sup> Additionally, preliminary data suggests that nasal cannular oxygen administered to patients who are SARS-Cov-2 positive at low flow rates of 6 L/min are much less likely to result in viral aerosolization.<sup>55</sup>

Given the above findings, several international groups have moved towards performing these procedures with low flow rates (5–10 L/min of  $\text{CO}_2$ ) and lower intraperitoneal pressures (8–10 mm Hg). There is an obvious hesitance to performing procedures at these new pressure settings. There is level 1 and SRMA data available on the feasibility of low-pressure insufflation states, facilitated by deep neuromuscular blockade. These studies have also demonstrated lower postoperative pain scores, earlier return of GI function with no difference in operative times, but overall improved surgical space as determined by distance from the sacral promontory to the skin<sup>56</sup> (Fig. 2).

### Surgical Technique

There are several maneuvers that can help to minimize viral exposure during the procedure. Regarding trocar insertion, we recommend minimizing incision length and avoiding any significant lateral movements on introduction to avoid any large subcutaneous space created around the trocar that may affect the tightness of the seal. Additionally, as demonstrated by Englehardt et al, the removal of trocars should be performed once the abdomen is desufflated, gently so as to avoid “splatter” of intraperitoneal contents further away from the abdomen.<sup>57</sup> It is also important for the surgical team to remain

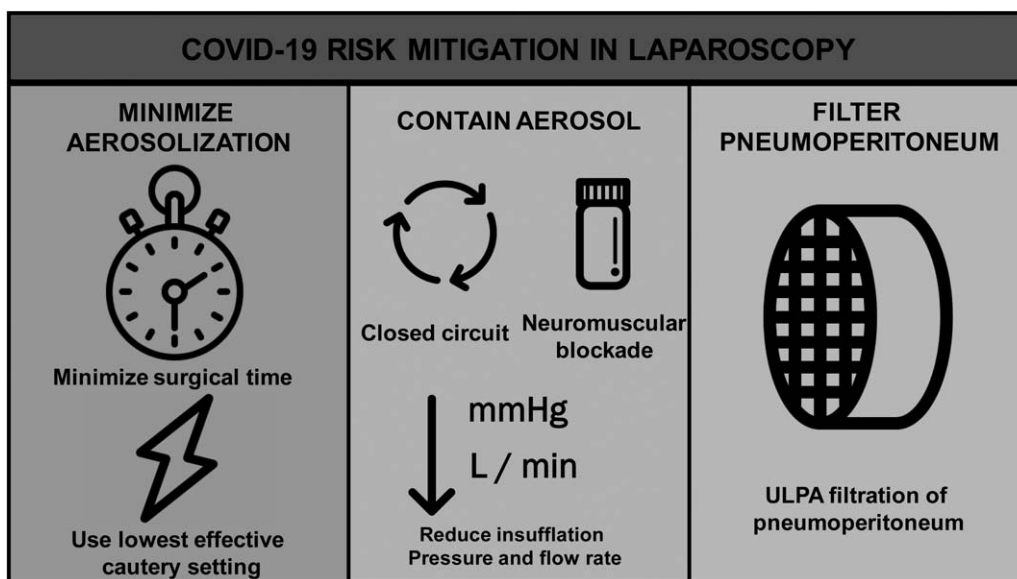


FIGURE 2. Principles of surgical technique to minimize risk with laparoscopy.

cognizant of the minimum instrument size capable of maintaining a seal within each type of trocar. Important devices to be aware of include smaller 3 mm instruments and laparoscopic suture ligatures (eg, Endoloop) that when left in the port can compromise the seal and allow for a leakage of gas. If a seal at a valve is felt to have been compromised, we recommend closing the port by placing a finger over the opening, ceasing insufflation, and desufflating the abdomen using the smoke evacuation or laparoscopic suction. We also recommend avoiding the use of vessel-sealing devices, ultrasonic devices, and harmonic scalpels as these may increase aerosolization of viral particles. Outflow during desufflation should be occur through the trocar in the least dependent position (typically an epigastric port). The safest approach would then be to perform a water-tight closure of the port and consider a different port site with a new functional port. The use of intraperitoneal gauze should be avoided, but if necessary, this should be removed at the end of the procedure after decompression to avoid aerosolizing contents to the room or obstructing the inflow or evacuation ports. Additionally, leaving intraperitoneal drains should be reconsidered given the exposure of intra-peritoneal fluids to the extra-abdominal environment.

**Terminating a Procedure**

At the completion of a procedure, it is important to ensure a standardized approach is established and to consider a simulation session for the first attempt. We recommend a similar approach to that listed in the SAGES guidelines.<sup>50</sup> Throughout the procedure, personnel in the operating room should be minimized to preserve PPE and minimize risk of exposure. When the procedure is completed and specimens are secured for subsequent removal, we recommend closing the insufflation port whereas keeping the smoke evacuation port open. It is also of crucial importance to notify your anesthesia colleagues to prevent the patient from emerging from general anesthesia prematurely, which may inadvertently result in increased intra-abdominal pressures, forcing air out of the abdomen. This will also help prevent the reflux of intraperitoneal contents back into the machine, which has been a recognized hazard.<sup>58</sup> Some have advocated for the use of a laparoscopic suction device to complete the suction of the abdominal pneumoperitoneum: caution should be taken in doing so as aerosolized intraperitoneal contents would be suctioned into the hospital’s system, the details of which likely vary from institution to institution. When decompressed, ensure the ports are removed slowly and carefully. All reusable instruments, even in SARS-Cov-2 negative patients, should be treated as potentially contaminated given the false negative rate of RT-PCR testing. Lastly, it is important to ensure that doffing PPE be performed in the company of an observer or doffing coach protect against mistakes that may result in contamination. At the completion of the procedure, it is also crucial to ensure enough time has elapsed according the institutional standards of the negative pressure environment for the air within the room to have been recycled before leaving the room. We have attempted to summarize our recommendations for conduct before and after the procedure as a perioperative “checklist” in Fig. 3.

**SOCIETAL GUIDELINES**

Several major surgical societies have released recommendations to help guide surgeons’ decision-making during the COVID-19 pandemic (summarized in Supplement 1, <http://links.lww.com/SLA/C210>). Most societies recommend postponing scheduled surgical and especially endoscopic procedures in light of the increased burden on the healthcare system posed by COVID-19 and the heightened risk to both patient and surgeon of exposure. All societies express confidence in the judgement of the surgeon for the ultimate decision of whether or not to operate, but the American College of Surgeons (ACS) and the

**COVID-19 LAPAROSCOPY CHECKLIST**

**D**onn personal protective equipment

**R**estrict personnel

**O**R with negative pressurization

**P**repare smoke evacuator with filter

PRE-OP

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POST-OP

**L**asting paralysis

**E**nd insufflation

**S**moke evacuation via epigastric port

**S**low removal of trocars

FIGURE 3. COVID-19 laparoscopy checklist.

harmonized United Kingdom guidelines recommend medical management for acute issues that are typically treated operatively (ie, appendicitis, cholelithiasis).<sup>1,2</sup> Regarding laparoscopy specifically, again the ACS and UK guidelines favor avoidance; however, SAGES, the European Association of Endoscopic Surgeons, and the Royal Australasian College of Surgeons state that little or no evidence exists to favor an open approach over a laparoscopic/robotic one.<sup>59,60</sup> PPE is recommended almost universally for all patients (regardless of test status), but only the ACS specifies that this includes N95 masks or powered air-purifying respirators. In terms of workflow, most guidelines recommend reducing the number of providers exposed, and intubating/extubating in negative pressure operating rooms with appropriate wash-out time between cases. Interesting technical recommendations include minimizing insufflation pressure, use of monopolar pencil cautery with smoke evacuators, use of filters when releasing insufflation, and performing stoma formation procedures over primary anastomosis to reduce the need for reoperation. The exception to most of these recommendations comes from the Royal Australasian College of Surgeons which has published a letter stating that they support the surgeon’s approach and make few other specific recommendations.<sup>60</sup> These guidelines are referenced with varying degrees of completeness, and we hope that our review can contribute to these guidelines moving forward.

**CONCLUSIONS**

The provision of minimally invasive surgical techniques during a pandemic such as the situation with COVID-19 needs to be approached with caution and meticulous preparation. We do believe that significant advantages, even as they pertain to controlling

and mitigating the inherent risks of transmission with surgery, are available with minimally invasive techniques, provided that the suitable equipment and expertise are present. In experienced hands, surgical teams can likely continue to offer the associated advantages of minimally invasive surgery over open techniques to patients in a safe and controlled fashion. We recommend against initiating one's minimally invasive practice during this unprecedented time. Surgeons should ultimately proceed with technical approaches they are comfortable with to ensure no added risk to the patient and operating room team occur.

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