Background: SARS-CoV-2 virus is largely transmitted via respiratory droplets and the highest transmission risks arise when undertaking aerosol generating procedures like laparoscopy. Most national societies had advised the urgent suspension of elective surgery with the focus shifting to emergency and cancer surgery only during this pandemic. However very little is known regarding the risks to the health care professionals undertaking emergency laparoscopic procedures. Aims and Objective: To demonstrate safety at laparoscopy by modifying the technique for safe management of patients during the COVID-19 pandemic. Design and Setting: This is an observational cohort study. This study was done at a tertiary care reference hospital for minimal access gynaecological surgery. Safety of 42 semi-urgent and emergency laparoscopic surgeries in patients was evaluated for a period of 5 months after taking informed written consent of patients to participate in the study. Materials and Methods: Use of double closed circuit laparoscopic suction evacuation and filtration systems with closed circuit anaesthesia with specialized Heat and Moisture Exchangers (HME) bacterial & viral (BV) filters to make laparoscopic surgery safe. Results: 57.14% of the patients were 41 years or more. 47.6% presented either with menorrhagia, irregular vaginal bleeding or post-menopausal vaginal bleeding and 26.19% patients were keen to conceive. In 50% patients, surgery was done in 60 minutes or less. Post-operatively, none of the patients had any complications and all were followed up for 14 days for COVID-19 infection. No staff, doctors or anaesthetist were detected COVID-19 positive during the follow up period. The limitation of the study was, that it was an observational study done in COVID-19 negative patients only. Conclusions: Safety at laparoscopy can be maintained when it is performed by an experienced surgeon who has full knowledge of safe laparoscopic techniques and performs it in the shortest time possible and with all due precautions.

Keywords: COVID-19, SARS-CoV-2, Minimally invasive surgery, Laparoscopy, Viral diffusion

Introduction

Laparoscopy is the most conventional approach for most abdominal and pelvic surgery. The novel nature of the severe acute respiratory syndrome coronaviruses-2 (SARS-CoV-2) pandemic presents several challenges to a laparoscopic surgeon and has disrupted our ability to offer timely procedures to patients with gynecological surgical indications due to increased risk of virus diffusion in the operating theater.

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during surgery. During the pandemic, elective surgeries were limited and only urgent and emergency procedures were performed.

Major concern during laparoscopy is the risk to anesthetist, surgeon, and operating room personnel due to aerosolization of viral particles during general anesthesia which involves intubation, extubation, and mechanical ventilation. It may produce airborne viral droplets in a coronavirus disease-2019 (COVID-19)-positive patient due to the high viral load in respiratory secretions posing one of the highest risks for aerosol generation.

A few papers[1,2] have mentioned the risk of aerosolization of viral particles through the pneumoperitoneum. Few papers have shown a correlation between increased pneumoperitoneum pressure and the number of cells found.[3] However, till date, no studies have identified SARS-CoV-2 in surgical smoke, and even if found, it is not known whether these viral particles are infectious.[4-6] The US and European Joint Professional Society statement endorsed that laparoscopy is a safe surgical approach during COVID-19 pandemic.[7]

Electrosurgery had no evidence for an increase in disease transmission. Therefore, due to the lack of data supporting the claim that COVID-19 virus spreads through the laparoscopic smoke plume or pneumoperitoneum, one cannot justify the use of laparotomy instead of laparoscopy.

**Materials and Methods**

Due approval of the Institutional Ethics Committee was obtained, which was granted for this observational study done from March 14, 2020 to August 14, 2020. Forty-two patients were evaluated for the feasibility to perform semi-urgent and emergency gynecological laparoscopic and hysteroscopic surgery at a tertiary care hospital. All these patients were tested negative for COVID-19 by reverse transcription–polymerase chain reaction (RT-PCR) test and were asymptomatic for 14 days prior to consultation.

All patients and their close contacts were triaged by filling a questionnaire before consultation. The patients were screened for temperature and SpO₂ before meeting the consultant and all guidelines as per the COVID-19 norms were followed. If a surgery was necessary, the patient underwent all necessary investigations including RT-PCR for COVID-19, 3 days prior to surgery. The patient was then requested for isolation till the surgery. Preoperative bowel preparation was done on the day before admission. On admission, only one relative triaged earlier was permitted in the hospital. Before surgery, the patients were counseled by the anesthetist and surgeon regarding the procedure and risks involved during the COVID-19 pandemic. Consent for said surgery, anesthesia, and operation during COVID-19 pandemic was obtained.

Heat and moisture exchanger (HME) bacterial and viral (BV) filter was fixed at the patient’s anesthesia gas outlet and at the inlet of Soda-bi-carb canister [Figure 1]. The anesthetist, surgeon, and operation theater (OT) staff donned adequate personal protective equipment (PPE) and used N95 mask with face shield. General anesthesia was given and the patient intubated under a specially designed hood and using a video laryngoscope [Figure 2]. The surgical team with adequate PPE entered the OT only after the patient was put in lithotomy position, painted, and draped. Pneumoperitoneum was created by disposable Veress needle and CO₂ was pumped from the insufflator through HME BV filter [Figure 3]. This device had a closed circuit to maintain the pneumoperitoneum and to facilitate smoke evacuation and filtration with a 0.1 µm ultra-low particulate air filter. The CO₂ insufflation pressure was kept to a minimum. Optical trocar was used as a primary port with care been taken that there is no leak of gas during withdrawal of trocar. Other ports were then inserted under vision. Pneumoperitoneum pressure was kept at 15 mm of mercury and optimal Trendelenburg was given. Laparoscopic surgery was done as per the indication. Right lower port was connected to a three-way cannula which was, in turn, connected to a suction tube which went below the 1% sodium hypochlorite solution in the Endomat suction bottle kept at low suction pressure with HME BV filter before the machine end [Figure 4].
allowed pneumoperitoneum release for better vision, evacuating smoke or plume which went directly into the 1% sodium hypochlorite fluid in a closed system. The laparoscopic suction system was connected to another Endomat suction bottle [Figure 5] and machine in a way that the tube dipped below the 1% sodium hypochlorite solution kept at low pressure (closed system) with HME BV filter before the machine end [Figure 6]. We also minimized exchange of instruments through the trocars to minimize gas leakage. Entire closed circuit systems used in laparoscopy and anesthesia with locations of the HME BV filters are highlighted schematically [Figure 7].

In laparoscopy, removal of the specimen is the most important step. This can be done either transabdominally or vaginally. During removal, the carbon dioxide inflow was stopped, and the right lower port three-way cannula was kept open to deflate the pneumoperitoneum. This method helped in removing the specimen without gas splatter. The same procedure was followed to deflate the abdomen for removal of tissue by in bag morcellation or removal of tissue in a bag from the abdomen. The potential leak from the vaginal opening or abdominal tissue extraction opening was prevented by a suitable barrier, i.e., vaginal tube etc., Once the specimen was removed, pneumoperitoneum was recreated for vault closure, checking hemostasis, etc., Once the surgery was over, carbon dioxide inflow was stopped, inflow was stopped and right lower port tap opened to remove the intraperitoneal carbon dioxide in sodium hypochlorite solution. Once the abdomen was completely deflated, all trocars were removed under vision.

To avoid viral diffusion, we performed laparoscopy with optimum intra-abdominal carbon dioxide pressures and...
optimal use of energy, which limited the production of the surgical plume. In addition, we used a smoke evacuation/filtration system which allowed controlled release and filtration of the surgical plume. The filter used during gas and plume evacuation was an ultralow particulate air filter rated to screen particles of 0.1 \( \mu \text{m} \) in diameter. All ports larger than 5 mm were closed as per the standard practice.

Further to increase the safety, the knob of the main cylinder of carbon dioxide was closed and the tubing of \( \text{CO}_2 \) inflow from the insufflator was connected to the Endomat tubing dipped in sodium hypochlorite so that no gas from tubing or within the insufflator would come in contact with the OT air system. Doffing of the PPE kit by all those involved in the surgery was done as per the guidelines. After the surgical team left the OT, the anesthetist and OT technician with proper PPE protection extubated the patient with a third dedicated suction emptying in 1% sodium hypochlorite solution. Once doffing of the PPE kit was done by the anesthetist and OT technician, the large bag containing all PPE and disposables was closed for safe disposal.

All patients were administered antibiotics and analgesics before shifting to the room/ward where only one nurse and attendant was allowed. Post surgery, the OT, equipments, and instruments were cleaned and sanitized as per the guidelines.

Statistical analysis: As we report our initial experience during the pandemic, a sample size calculation was not done. All the results are expressed as actual numbers and percentages.

| Age in years | Number of patients |
|--------------|--------------------|
| <30          | 5 (11.9)           |
| 31-35        | 7 (16.66)          |
| 36-40        | 6 (14.28)          |
| 41-45        | 10 (23.8)          |
| 46-50        | 6 (14.28)          |
| 51-59        | 3 (7.14)           |
| 60 or more   | 5 (11.9)           |

Figure 6: Two heat and moisture exchangers + bacterial and viral filters protecting two Endomats: A (red arrow) flow of gas from suction bottle 1 toward Endomat 1 protected by heat and moisture exchangers + bacterial and viral filter, B (blue arrow) flow of gas from suction bottle 2 toward Endomat 2 protected by heat and moisture exchangers + bacterial and viral filter

Figure 7: Master schematic representation of the entire assembly: A closed circuit for anesthesia gas inflow from machine to endotracheal tube and a return of gases with heat and moisture exchangers + bacterial and viral filters protecting soda-bi-carb canister. Another closed circuit from \( \text{CO}_2 \) Insufflator with Heat and Moisture Exchangers + bacterial and viral filter for inflow tubing to primary trocar. Right lower port through a three-way cannula is connected to smoke filter and tubing which goes to Endomat bottle 1. The laparoscopic suction tubing goes to Endomat bottle 2. Both the Endomat bottles have a long tube which is submerged below sodium hypochlorite solution in the bottle. The other tubings from the bottles go through heat and moisture exchangers + bacterial and viral filters to Endomat machines set at a low pressure of 50–100 mmHg.
RESULTS
About 57.14% of the patients were 41 years or more [Table 1]. The indications for surgery are highlighted in Table 2. Maximum patients (47.6%) presented with menstrual abnormalities such as menorrhagia, irregular bleeding, or postmenopausal bleeding. The procedures done included hysterectomy, myomectomy, ovarian cystectomy, ectopic pregnancy with appendicectomy, hysteroscopy, and hysterectomy for a large 28 weeks size uterus. Only two patients had malignant lesion, whereas the rest (40) were benign [Table 5].

In one case who had recurrence after surgery for endometrial cancer, we performed laparoscopic excision of nodes and large segment of rectosigmoid bowel excision and anastomosis.

In 50% of patients, the surgery was completed within 60 min [Table 4]. Maximum time (exceeding 90 min) was required in three cases: laparoscopic excision of nodes with large segment of rectosigmoid bowel excision and anastomosis, laparoscopic myomectomy for a large 12 cm fibroid, and laparoscopic hysterectomy for a large 28 weeks size uterus. Only two patients had malignant lesion, whereas the rest (40) were benign [Table 5].

Postoperatively, none of the patients had any complications and all were followed up for 14 days for COVID-19 infection. No staff, doctors, or anesthetist were detected COVID-19 positive during the follow-up period.

DISCUSSION
With due precautions, one should try and minimize potential or theoretical risks of virus transmission during COVID-19 pandemic at laparoscopy. The surgical team should minimize exposure during intubation and extubation and all OT personnel should don adequate PPE kits, including face shields, N95 masks, gowns, and gloves. The other measures include use of devices to filter released CO₂ for aerosolized particles, minimizing medical staff inside the OT and screening of patients before planned surgery and postponement of surgery on suspected or documented SARS-CoV-2-positive patients until full recovery. There is a risk to the operating team to COVID-19 contaminated aerosol through gas leaks after a sudden release of trocar valves, via non-airtight exchange of instruments or by gas leak through the tissue extraction incision site. This is particularly important in relation to evacuation of pneumoperitoneum during laparoscopy. One could reduce CO₂ release by: (a) closing the port taps before insertion, (b) attaching a CO₂ filter to one of the ports for smoke evacuation if needed, (c) not opening the tap of any ports unless they are attached to a CO₂ filter or being used to deliver the gas, (d) reducing the introduction and removal of instruments through the ports, (e) deflating the abdomen with a suction device before removing the specimen bag from the abdomen, (f) deflating the abdomen with an open tap of right lower port attached to a three way which goes to sodium hypochlorite in the suction bottle and via the port with a CO₂ filter at the end of the procedure, and (g) minimizing the use of cautery.

Further, for decades, laparoscopic surgeries are done in patients of HIV and hepatitis B and C. Kwak et al. studied hepatitis B virus in surgical smoke, hepatitis B RNA was seen in 10 of 11 cases, but it did not spread if disposables were thrown.

Even if it is assumed that limited viral particles may become airborne during intubation and extubation or through pneumoperitoneum, the OT is one of the safest

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### Table 2: Indication for surgery

| Indication for surgery                  | n (%) |
|-----------------------------------------|-------|
| Menorrhagia/irregular bleeding PV        | 14 (33.33) |
| Postmenopausal bleeding                 | 6 (14.28) |
| Pain in the abdomen                     | 6 (14.28) |
| Dysmenorrhea                            | 3 (7.14)  |
| Keen to conceive                        | 11 (26.19) |
| Recurrence after surgery for Ca endometrium | 2 (4.76)  |
| PV: Per vaginum                         |       |

### Table 3: Procedure done

| Procedure done                                                | n (%)    |
|---------------------------------------------------------------|----------|
| Hysterectomy                                                  | 17 (40.47) |
| Myomectomy                                                    | 6 (14.28)  |
| Laparoscopic excision of nodes, large segment of rectosigmoid bowel excision, and anastomosis | 2 (4.76)  |
| Laparoscopic cystectomy                                       | 5 (11.9)   |
| Hysterolaparoscopy with hysteroscopy polypectomy              | 8 (19.04)  |
| Hysterolaparoscopy                                            | 3 (7.14)   |
| Laparoscopy for ectopic pregnancy with appendicitis           | 1 (2.38)   |

### Table 4: Time taken for surgery

| Time taken (min) | n (%)    |
|------------------|----------|
| <30              | 11 (26.19) |
| 31-45            | 3 (7.14)   |
| 46-60            | 7 (16.66)  |
| 60-75            | 10 (23.8)  |
| 76-90            | 8 (19.04)  |
| 90-120           | 3 (7.14)   |

### Table 5: Histopathology of specimens

| Histopathology                | n (%)    |
|-------------------------------|----------|
| Benign lesions                | 39 (92.85) |
| Malignancy                    | 2 (4.76)  |
| Ectopic pregnancy + appendicitis | 1 (2.38)  |
places in the hospital to avoid COVID-19 exposure because of the availability of air filtration/circulation units in most OTs. Moreover, most operating theaters have positive pressure relative to the surrounding air in the adjacent areas to prevent the flow of air from less sterile areas into a more sterile one. However, one must remember that the positive pressure environment within the OT makes the spread of aerosols faster, posing an increased risk of airborne viral transmission. This makes a negative-pressure environment ideal to reduce viral dissemination beyond the OT but may not be available in most OTs. Instead, one could use high-frequency filtered air exchanges to reduce viral load within the OT.\(^{[13]}\)

We avoided risk of viral transmission and aerosolization by proper use of PPE kit for all OT personnel, using lower intra-abdominal carbon dioxide pressures with optimal use of energy, minimizing the amount of Trendelenburg and use of filters for gas and plume evacuation which was done under sodium hypochlorite solution. We paid special attention at port sites to prevent explosive dispersion of body fluids both at the insertion/removal of trocars and specimen retrieval.

Several societies suggested in their guidelines to perform laparotomy rather than laparoscopy during the COVID-19 pandemic because of the theoretical risk of aerosolization. However, one must remember that laparotomy has more disadvantages due to the prolonged hospital stay and bed use, an increased likelihood of intensive care unit stay, and greater risk of surgical complications and of COVID-19 exposure for both the patient and health-care providers. Moreover, smoke evacuation/filtration systems can be used during laparoscopy and not at laparotomy. Thus, laparoscopy offers the unique advantage of shorter stay with ability to almost entirely curtail the surgical plume in the abdominal cavity with usage of tightly fitting laparoscopic ports and an evacuation/filtration system. We used a containment bag for all tissue extraction, limiting the release of gas during tissue removal and loss of pneumoperitoneum.

In the past, similar respiratory viruses, such as influenza and other coronaviruses (SARS and Middle East respiratory syndrome-CoV), have not shown viral disease transmission through surgical plume or laparoscopic gas during previous viral epidemics.\(^{[14]}\) Although the DNA of blood-borne viral pathogens, like hepatitis B and HIV, have been detected in surgical plume after usage of surgical energy (e.g., electrosurgery, laser, and harmonic scalpel), there is no evidence indicating that usage of electrosurgery during laparoscopy increases the risk of disease transmission through the surgical plume or pneumoperitoneum.\(^{[12]}\)

**Conclusions**

Today, our knowledge about SARS-CoV-2 virus is still limited. Moreover, the possible risks for health professionals and the risks from operating on an asymptomatic patient positive for SARS-CoV-2 are still unclear. Ideally, therefore, it is best to screen all patients before surgery and when not possible, PPE should be used and all the strategies to decrease aerosol diffusion in the operating theater should be followed.

We were able to minimize the release of potential airborne virus into the OT environment, using adequate PPE kits for all personnel and evacuating the surgical gas and smoke using filtration system within sodium hypochlorite solution and avoiding a sudden release of the pneumoperitoneum both during tissue extraction and removal of trocars along with a closed circuit general anesthesia with use of special HME + BV filters. Although the number of infertility patients in this case series was less compared to other indications, we can extrapolate the safety of the described procedures for laparoscopy in all groups.

Thus, laparoscopy when critically performed with all precautions will achieve the goal of optimizing patient care and outcomes while minimizing the risk of transmission of COVID-19 to the surgical team and all OT personnel. An experienced surgeon who has full knowledge of safe laparoscopic procedures can perform the surgery in the shortest possible time. Laparoscopy remains the preferred surgical approach for gynecological surgeries during the COVID-19 pandemic when all due precautions are taken and continue to offer more health benefits.

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**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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