Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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COVID-19 in Women's health reducing the risk of infection to patients and staff during acute and elective hospital admission for gynaecological surgery

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A B S T R A C T

The novel coronavirus SARS-Cov-2 has changed healthcare on a worldwide scale. This highly contagious respiratory virus has overwhelmed healthcare systems. Many staff were redeployed, and there was widespread cessation of non-urgent outpatient clinics and surgery. Outpatient clinics and theatre areas were converted to COVID-19 wards and intensive care units. Following the first peak, services began to recommence with new triaging and prioritisation guidance to safeguard patients and staff. Different countries and healthcare systems produced differing guidance and, in particular, variation in the best approach to continuing acute and elective surgical procedures. This chapter collates and evaluates the increasing international literature concerning the surgical management of gynaecological conditions during the pandemic, such that clear inferences, recommendations and guidance can be generated to aid clinical practice and safeguard against further major disruption arising from further COVID-19 peaks. The available data are assessed within the context of the current phase of the COVID-19 pandemic.

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Introduction

In late December 2019, the first case of a new respiratory viral disease called coronavirus disease 2019 was reported. This disease was caused by the highly contagious SARS-Cov-2, a β coronavirus measuring between 50 nm and 200 nm in diameter, which is spread primarily by the respiratory route. The virus spread rapidly across continents, overwhelming many healthcare systems, and on the March 11, 2020, the World Health Organization (WHO) declared COVID-19 as a global pandemic.

As it continued to spread around the world, the crippling impact of the virus on healthcare systems and the wider society was quickly realised. In order to ease the pressure on health services, national lockdowns were imposed across the world, with restrictions on travel, work and recreation. Face-to-face clinical appointments were all but stopped, and non-essential surgery was curtailed, with only emergency and prioritised cancer surgery continuing. The objective was to reduce viral transmission such that the number of infected people needing healthcare could be reduced as rapidly as possible, called 'flattening the curve'. In this way patient outcomes could be optimised and scarce and diminishing healthcare facilities conserved. Large numbers of staff were deployed to support the frontline COVID-19 efforts, and the facilities such as theatres and outpatient areas were converted into much-needed COVID-19 wards and intensive care units.

After 'flattening the curve' of the first peak of SARS-CoV-2, the issues of long surgical waiting lists due to the cancellation of planned procedures and the resultant negative impact on patients' mental and physical well-being became apparent. The need to recommence benign gynaecology services and accept the potentially higher risks of COVID-19 transmission with potential increased surgical morbidity and mortality needed to be weighed against the morbidity of patients' ongoing and untreated symptoms and the impact of the surgical delay on women's quality of life. These challenges have become more evident with further waves of new-variant SARS-CoV-2 infection leading to further peaks of infections, hospital admissions and deaths and ever-increasing demands on already stretched healthcare services.

The aim of this review is to evaluate the evidence to inform the best approach to continuing acute and elective gynaecological procedures, even in the face of further COVID-19 peaks, in order to reduce the risk of transmission of SARS-Cov-2 to staff and other patients while also reducing morbidity and potential mortality in patients undergoing elective gynaecological surgery.

Viral transmission

The coronavirus (SARS-CoV-2) responsible for COVID-19 is known to be transmitted through the respiratory tract and spread by fomites, contaminated surfaces onto which the virus has fallen, aerosols (particles less than 5μ which evaporate in the air, leaving droplet nuclei that are able to remain in the air for hours) and droplets (particles greater than 5μ which fall to the ground almost immediately by gravity) and on occasion can result from airborne spread (particles that remain suspended in the air and travel a distance).

Dampening the transmission of SARS-CoV-2 is primarily achieved by social distancing, the wearing of appropriate personal protective equipment (PPE) and hand washing. In the surgical environment, the highest risk of transmission is from aerosol generation at intubation and extubation during general anaesthesia (GA) due to the high viral load in respiratory secretions [1]. The next greatest risk is through aerosol-generating procedures (AGP) specific to surgical procedures, although the true risks of this method of transmission are uncertain [2].

Frontline staff are largely at risk of becoming infected when undertaking AGP and also via direct contact with patients where PPE and social distancing have not been appropriately utilised. The risk of developing COVID-19 in this way is thought to be in the region of 3% and usually tends to occur where healthcare workers care for and are exposed unknowingly to patients who are COVID-19-positive and without appropriate PPE [3].

Transmission and body fluids including the female reproductive tract

Other methods of human-to-human transmission of the virus via blood and faeces have also been described [4,5]. SARS-COV-2 viral RNA has been detected in faeces in up to 67% of COVID-19 cases [5,6]; however, live infectious particles have only been described in a small number of cases (1%–2%) [5]. While it is clear that this route of transmission is possible, the low prevalence of live viral particles suggests a reassuringly low risk of transmission during gynaecological surgery.

SARS-COV-2 RNA viraemia is detected in 97% of COVID-19 cases; however, the actual viral RNA load is low, suggesting a very small risk of transmission from exposure to infected blood within CO_2 aerosols or smoke during surgery [7].

Of concern to gynaecologists would be the possibility of transmission of the virus through the female reproductive tract. Initial reports suggested that the virus was not present in the female genital tract [6,8]. However, a later report by Schwartz and colleagues revealed the detection of SARS-CoV-2 in vaginal swabs using reverse transcriptase polymerase chain reaction (RT-PCR) in 2 of 35 patients studied [9]. Reassuringly, there have been no reports of the virus being transmitted through the vaginal secretions. Conflicting evidence exists for the presence of SARS-CoV-2 in the semen of infected males. Li et al. described the presence of SARS-CoV-2 in 16% of semen samples from 38 men tested during the acute and recovery phase of COVID-19 [10]. Conversely, a smaller study of 12 men in the acute and recovering phase of COVID-19 by Song et al. found no evidence of SARS-CoV-2 in semen samples [11]. The virus has also been found in the urine of patients infected by SARS-CoV-2 with a low rate of positivity [12]. Based on all the available evidence, it appears there is a very low risk of SARS-CoV-2 viral transmission via the female genital tract particularly in asymptomatic patients [13], especially if they have negative PCR tests.

Surgery as a route of transmission of SARS-CoV-19

Another potential theoretical source of transmission is through aerosolisation of peritoneal fluid during surgery; however, evidence is conflicting. Coccolini and colleagues reported on the first case of SARS-CoV-2 found in the peritoneal fluid of a COVID-19 patient [14], while conversely, Ngaserin and colleagues reported the absence of SARS-CoV-2 in peritoneal fluid in an infected patient undergoing a laparoscopic appendicectomy [15].

Energy modalities and surgical smoke as possible vectors of transmission

Anxieties arose from the possibility of SARS-CoV-2 within surgical smoke, generated when using energy-generating devices (electrosurgery, lasers or ultrasonic devices) during gynaecological surgery, acting as a potential source of transmission.

Surgical smoke generation or 'plume' is the gaseous by-product that is created by energy-generating devices during surgery. At surgery, the heat produced by the action of energy modalities on tissue cells causes the affected cells to rupture at boiling point and produce a plume that can contain dangerous substances; at the same time, the surrounding cells become charred, causing toxic necrosis and the release of contaminants into the atmosphere, including viral particles [16]. There is evidence that viruses other than SARS-CoV-2 exist in surgical smoke plumes, but evidence of transmission is rare [17]. The potential for transmission is extrapolated from other pathogens and evidence gathered from previous pandemics.

Activated Corynebacterium, human papillomavirus (HPV), hepatitis B virus (HBV) and human immunodeficiency virus (HIV) have been detected in surgical smoke [18–21]. The presence of HPV DNA has been reported in approximately 40% of smoke plumes following loop excision biopsy of the cervix [22]. Liu and colleagues outlined HPV transmission in four cases, linking surgical smoke to the transmission of HPV in previously fit healthcare workers undertaking benign gynaecological surgery [16]. In HBV-positive patients undergoing operative laparoscopic procedures, the presence of HBV has been found in surgical smoke in over 90% of cases [23].

Initially, NHS pandemic infection prevention and control guidelines suggested that high-speed devices may generate aerosols [24]. Ultrasonic devices, being high-frequency oscillating devices,

could thus hypothetically add to the risk [25]. However, for such a risk to exist, there would need to be evidence of viral particles within the plume and evidence of stability of the virus within the plume, coupled with evidence of virulence of the particle and transmissibility. To date, there is no evidence of viral-particle transmission within aerosols generated by ultrasonic devices [21]. To date, there is no evidence that the SARS-CoV-19 virus is found in any smoke plumes generated by the multitude of energy-generating devices (monopolar, bipolar, ultrasonic) used in minimal access or open surgery; however, there remains a theoretical risk [26,27], and thus protective precautions need to be taken.

Minimal access or open surgery

At the onset of the pandemic, the Royal College of Surgeons of England (RCS) [28] advocated the use of open surgery over laparoscopic surgery because of the perceived risk to healthcare workers, although joint UK recommendations from the British Society of Gynaecological Endoscopy and the Royal College of Obstetricians and Gynaecologists adopted a cautious but more balanced tone in the absence of clear data [29]. Some believed that the CO_2 pneumoperitoneum required for laparoscopic procedures resulted in the stagnation of contaminants, including viral particles that could subsequently become aerosolised during the release of CO_2, such as during the removal of trocars port or specimens. There is however little evidence against using the minimal access approach to surgery [30,31]. The advantages of minimal access surgery over open surgery are well documented, including decreased blood loss, decreased hospital stay, less pain and earlier return to normal activity [32,33], and thus the use of minimal access surgery would meet the key objectives of managing the pandemic, i.e., reducing hospital stay and increasing bed capacity, reducing time spent and potential exposure to the virus in a hospital and helping 'flatten the curve'.

Furthermore, Mintz and colleagues, in their narrative review, concluded that if laparoscopy is performed in a closed cavity allowing containment of smoke and aerosols with smoke evacuation systems, it may be safer for patients and healthcare workers, as long as there is no contraindication for laparoscopy [34]. In an HPV study by Ferenczy and colleagues, they concluded that with the use of evacuation systems and PPE, there was no evidence of viral contamination on the skins of surgeons undertaking procedures with energy devices [35]. Thus, with the novel SARS-CoV-19 virus, though there is a lack of evidence of superiority of open surgery over laparoscopic surgery [36], every means should be taken to protect healthcare workers from possible contamination [37].

Smoke extraction filters

Mechanical filters capture smoke close to the source of production, minimising exposure to healthcare practitioners in the theatre environment, and maintain a clear operating field. High-efficiency particulate filters are able to filter suspended compounds, retaining particles of size greater than 0.3μ with an efficiency of 99.7%, while ultra-low particulate air (UPLA) filters have an efficacy of 99.9% for particles greater than 0.1μ [17]. The most effective filter is the triple filter system, which consists of a UPLA, a pre filter and a charcoal element that captures toxic fumes and vapours. Some devices have the ability to maintain low intraperitoneal pressures and also eliminate particles, e.g., Airseal™. Other non-filtration devices, such as Ultravision™, prevent the build-up of smoke and particles electrostatically to maintain a clear field, negating the need to vent smoke into the theatre environment [38]. However, the use of these devices is often limited by the cost of disposables and maintenance, as they are not as cost-effective as simple filtration devices, such as the ClearFlow ultra™ (LaproSurge Ltd UK) device, that meet the same regulatory particle extraction standard [39]. A summary of commercially available smoke/gas filtration and evacuation systems is presented in Table 1 [17,40].

Safe surgical technique

In the first peak of the pandemic, a number of surgical guidelines were developed internationally to provide necessary information, from experiential learning, about safe operating amid COVID-19. Many

Table 1
Commercially available smoke/gas filtration and evacuation systems.

Company	Alessi Surgical	Boerhringer Laboratories	Bowa	Braun Aesculap	CONMED	Cooper Surgical®	Ethicon	ICM Medical	Lexion Medical	Medtronic	Olympus	Stryker	Northgate	Karl-storz	Symmetry Surgical	Palliare Ltd
Product name	Ultravision		She Sha Smoke Evacuation System	AESCULAP® Flow 50 insufflator	Airseal® (laparoscopic) PlumePen® (open) Buffalo Filter® Smoke management	SeeClear Plume-away	Megadyne Smoke Evacuators MegaVac PLUS MegaVac MiniVac	Crystal Vision 450-D (lap) PenEvac® (open)	PneuView XE AP50/30	ValleyLab RapidVac	UHI-4	Pneumoclear PureView Neptune (open) SafeAir (open) Photonblade (open) Smoke Evac Retractors (open)	Nebulae I system	S-Pilot (031,111–10 & 031, 110–10)	Bovie® Smoke Shark II	EVA 15 insufflator
Open	No	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	No
Laparoscopy	Yes	yes	Yes	Yes	Yes	Yes	MegaVac PLUS only	Yes (Model 450-D)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ULPA	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Micron filtration	0.12–0.25	NA	0.1–0.2	0.051	0–0.12	0.1	0.1	0.03	0.01	0.1–0.2	NA	0.051–0.1	0.12	0.3–0.027	0.1–0.2	0.04
Passive or active evacuation	Active	Active	Active	Active	Active	Passive	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active

Table adapted from SAGES COVID-19 Medical Device Repository [40].

of the earlier recommendations suggested that open surgery may be the safest route to take, especially during general/bowel surgery [28].

However, as understanding of COVID-19 pathogenesis and transmission improved, the surgical community began to return to the more favoured minimally invasive approach, with the development and implementation of specific laparoscopic recommendations by a number of key gynaecological surgical societies [29,41,42]. Gynaecological minimal access surgery is recognised as having reduced surgical operation time, reduced inpatient recovery time and also improved surgical outcomes and reduced complications. These factors have important advantages, as they all contribute to the reduction of transmission of COVID-19 and, importantly, the morbidity associated with contracting the virus in a hospital.

A review of the current guidance and recommendations from gynaecological, endoscopic and minimal access societies and agencies is summarised in Table 2 [29,42–52]. The guidelines are broadly consistent in their recommendations to mitigate risks of viral transmission during surgery. It should be noted that the absence of 'ticks' within Table 2 does not suggest conflict but rather represents variation in the specific type and details of recommendations presented. Only two of the 11 international-society recommendations specifically advocated open as opposed to laparoscopic surgery. A specific recommendation for laparoscopic intervention over laparotomy was limited to one society, with all other societies specifying a preferential route for abdominal surgery in the context of the COVID-19 pandemic.

There was a clear consensus on using techniques that would minimise the formation of bioaerosols and the spread of viral particulate from the abdominal cavity, which include minimisation of the use of electrocautery devices and liberal use of suction devices.

Measures required to keep patients, theatre personnel and surgeons safe

In addition to ensuring safe surgical practice, care pathways are needed to keep patients, theatre personnel and surgeons safe, including the organization of theatre and ward infrastructure, preoperative workup including viral screening and provision of information to staff and patients. A summary of these considerations, including an interpretation of the data in Table 2 regarding surgical recommendations, is provided below:

1. Non-surgical treatments should be utilised where possible to reduce the risk of horizontal transmission of the SARS-CoV-2 virus to reduce the need for hospital admission, provided they are a safe alternative.
2. Hospitals should have clear pathways and make theatre allocations to separate the following groups of patients:
   a COVID-19-positive patients;
   b Patients with clinical emergencies.
      i On these patients, if there is time to delay surgery, then COVID-19 as reverse RT-PCR testing should be performed depending on the turnaround time, which can range from 24 h to 48 h.
      ii Rapid testing, which has a 30-min turnaround time, may be appropriate. However, these tests are not as accurate as RT-PCR when used in an asymptomatic population and have a documented sensitivity of only 48.9% [54]. Sensitivity can be as high as 95% in patients with a high viral load; however, such tests have not been validated for screening use prior to surgery.
   c Trauma patients; and
   d Patients undergoing elective/planned surgery.
3. Patients should be assessed for the risk of potential SARS-CoV-2 viral infection. Universal SARS-CoV-2 virology screening should be undertaken in all patients undergoing surgery. Patients testing negative can proceed with the standard laparoscopic technique and routine surgical infection control procedures.
4. If urgent surgery is required and testing is not possible, the case should be managed as a suspected COVID-19 case, taking precautions.

Table 2
Review of the recommendations from national and international societies.

Recommendations	SAGES & EAGES Guideline [43]	RCOG–BSGE Joint Guideline [29]	JMIG–AAGL Joint Statement [42]	SERGS [44]	ESGE [41]	AGES (Nigeria) [46]	COGA (China) [49]	IRCCS Italy Practical recommendations for gynaecologic surgery [50]	Polish Society of Gynaecologists and Obstetricians [51]	Indian Association of Surgical Oncology [52]	ISGE Guidelines [53]
Open approach						✓		✓			
Laparoscopic approach									✓		✓
Robotic approach				✓							
Disposable operating equipment											✓
Negative pressure room intubation/ extubation							✓				✓
Most experienced surgeon						✓	✓				✓
Infection prevention & control/PPE	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Regional anaesthesia/sedation			✓					✓			
Use of swabs/suction/retrieval devices to minimise droplet transmission & explosive dispersion of body fluids		✓	✓	✓	✓	✓					
Closed-circuit smoke evacuation/ ultra-low	✓	✓		✓							
Particulate air filtration systems	✓				✓			✓		✓	
Low power setting of electrocautery	✓		✓	✓	✓			✓	✓	✓	✓
Minimal use of energy devices	✓		✓		✓	✓		✓	✓	✓	✓
Minimisation of introduction and removal of instruments through ports as much as possible					✓			✓	✓	✓	
Avoidance of ultrasonic dissectors and bipolar devices										✓	
Small port incisions	✓									✓	✓
Balloon/self-sealing trocars	✓		✓	✓					✓	✓	
Low CO_2 pressure	✓		✓		✓						✓
Closed port taps prior to insertion					✓				✓	✓	
Low CO_2 pressure for insertion and removal of specimen and devices				✓					✓	✓	✓
Pneumoperitoneum evacuation via filtration system	✓		✓	✓							✓
Avoidance of using 2-way pneumoperitoneum insufflators											
Avoidance of rapid desufflation when removing tissue			✓	✓					✓	✓	
Closing of evacuation of all gas at the end of the procedure			✓	✓	✓				✓	✓	✓
Reduction in Trendelenburg position time										✓	

5. Minimal access procedures should be undertaken by or under the supervision of the most experienced surgeon available to ensure full knowledge of the safe laparoscopic procedures to be followed and to ensure that the procedure is performed in the shortest time possible.
6. To protect operating staff
   a. PPE must be made mandatory for all theatre personnel (i.e., disposable gloves, disposable fluid-resistant gowns, filtering face piece class 2 or 3 or N95 respirator and disposable eye protection).
   b. In PCR-negative patients, precautions still need to be taken because of the limitations of a negative test and the variability in the penetrability of different surgical/FFP3 masks, particularly if the masks become moist during surgery. Ideally, the use of PPE during surgical procedures should be driven by the background prevalence of COVID-19 in the community. However, most surgeons are unaware of their background prevalence, and most would use maximum PPE precautions irrespective of the COVID-19 status of patients in the operating theatre or their background risk [55]. Local protocols should be developed and followed.
   c. Theatre staff need to be well versed in self-protection strategies against suction materials and blood-contaminated areas in theatres and in laparoscopic suction in line with local protocols.
7. To aid artificial ventilation
   a. Operating pressures should be kept as low as possible; and
   b. The time spent in the Trendelenburg position should be minimised.
8. To prevent and manage aerosol dispersion
   a. Take caution and care during insufflation;
   b. Pay special attention to port sites to prevent explosive dispersion of body fluids during both the insertion/removal of trocars and specimen retrieval;
   c. Limit the number of incisions where possible, although there should be enough port sites to allow safe and expeditious surgery;
   d. Ensure that incisions are of appropriate size to prevent leakage during procedures;
   e. Use balloon-inflatable ports to ensure they do not slip;
   f. Minimise exchange of instruments to minimise leakage;
   g. Employ electrosurgical and ultrasonic devices in a manner that minimises surgical smoke production with low power settings; and
   h. Use suction devices, smoke evacuation filters, retrieval devices and swabs to prevent aerosol transmission—remove smoke, aerosol and the CO_2 pneumoperitoneum during surgery and avoid explosive dispersion of body fluids when removing trocars and retrieving specimens.
9. Only evacuate surgical smoke via the tap on ports when attached to a smoke evacuation filter and/or by direct suction using a vacuum suction unit.
10. Only evacuate the pneumoperitoneum via direct suction using a vacuum suction unit.

Specific surgical considerations pertaining to gynaecology

Specific gynaecological surgical considerations when operating during COVID-19 times have been well described [29,30,41,56] and include:

Hysteroscopic surgery

- Follow best practice for diagnostic/operative hysteroscopy procedures to minimise the risk of general contamination from body fluids.
- Use mechanical instruments/tissue removal systems if feasible to minimise the generation of surgical smoke.
- Where electrosurgery is used, facilitate the extraction of surgical smoke by using active suction connected to the outflow in a closed circuit.

Laparoscopic surgery

- Utilise suction devices, smoke evacuation filters and retrieval devices to prevent aerosol transmission, and remove smoke, aerosol and the CO_2 pneumoperitoneum during procedures.
- Avoid uncontrolled dispersal of surgical smoke into the theatre atmosphere:
  - o Only evacuate surgical smoke via the tap on ports when attached to a smoke evacuation filter or by direct suction using a vacuum suction unit.
- Avoid uncontrolled dispersal of the CO_2 pneumoperitoneum into the theatre atmosphere:
  - o Only evacuate the pneumoperitoneum via direct suction using a vacuum suction unit.
- Avoid explosive dispersion of body fluids when removing trocars and retrieving specimens:
  - o Pay special attention in cases of laparoscopic hysterectomy, as there is a high risk of explosive dispersion of body fluid when the uterus is removed from the vagina.

The patient/PCR testing triage

During the pandemic, in order to flatten the infection/hospital admission 'curve' and to appropriately apportion resources to fight the pandemic, where surgery could be safely avoided, first-line medical or conservative management is advised [29].

Those undergoing surgery need to be triaged based on viral RNA detection in nasal swabs using RT-PCR tests [57]. Available tests have a sensitivity range of 71%–98% [58]. The accuracy of the test is also user-dependent and relies on accurate sampling from the nasopharynx. The probability of a false negative test is highest 4 days before the onset of symptoms, with the lowest probability being on the day of onset of symptoms [59]. Clinicians thus need to interpret these tests based on the pre-test probability of disease. In an illustration by Watson and colleagues of 100 patients with a pre-test probability of 80%, RT-PCR test sensitivity of 70% and specificity of 95%, 56% of patients would be true positives, 19% would be true negatives, one person who tests positive would not have COVID-19, and 24% would be negative but have COVID-19 [60]. This illustrates that when screening patients prior to surgery, PCR testing alone will not identify all patients; thus, the test needs to be combined with a detailed history and temperature checks in RT-PCR negative patients and should be applied for all emergency patients even if they test negative.

Surgical outcomes and COVID-19 infection

Studies have highlighted that clinical outcomes appear to be worse in asymptomatic patients undergoing surgery with undetected COVID-19, although the evidence remains limited [61,62]. The CovidSurg Collaborative published results on the global experience of operating on patients with a peri-operative SARS-CoV-2 infection. It highlighted a significantly high overall mortality of 23.8%, citing 19.1% and 26% mortality in elective and emergency surgery, respectively. Of those with peri-operative SARS-CoV-2 infection, 51.2% developed a pulmonary complication, namely adult respiratory distress syndrome (ARDS), pneumonia and the unexpected need for post-operative ventilatory support. The added risks may be proportional to age, sex, surgical complexity and patient co-morbidities; however, these potential adverse outcomes must be taken on board when planning and prioritising surgery during COVID-19 times and incorporated fully into patient counselling and consent. For elective surgery, when risk mitigation strategies are employed, morbidity and the risk of contracting COVID-19 perioperatively has been shown to be lower when patients are managed in COVID-19-free pathways [63,64].

Re-introduction and maintenance of benign gynaecology services

After the initial and subsequent lockdown periods in the UK, the evidence was clear that patients were suffering due to delays in surgical treatment in gynaecology [65]. Negopodiev and colleagues, using a Bayesian beta-regression model, estimated that more than 28 million operations had been postponed worldwide during the initial 12-week pandemic peak, and that it would take a median of 45

weeks to clear the backlog [66]. Following the 3-month lockdown in the UK, it was estimated that there were approximately 2.1 million patients waiting for elective surgery. This continues to increase on a daily basis with the added winter pressures, the extra burdens on NHS services, the unknowns of new COVID-19 strains, the increasing cases and potential future COVID-19 peaks.

Rapid scaling up of surgery was undoubtedly needed to prevent this backlog from increasing further, but gynaecological surgical services needed to be safe, sustainable and resilient to pressure particularly any potential future COVID-19 peaks. High surgical standards must be maintained, to ensure patient safety and optimise clinical outcomes. One concern expressed is that patient care could be compromised if low volume, less experienced surgeons are utilised in an attempt to expedite the large backlog of patients. Moreover, patient choice may be compromised if less invasive laparoscopic surgery is not offered, because such surgeons do not have the necessary competencies [67].

Operating theatre environment

The theatre environment is designed to prevent intraoperative contamination. Most standard operating theatres have a positive pressure relative to the surrounding air (e.g., in corridors and adjacent areas) to prevent the flow of air from less sterile areas into a more sterile one. However, this positive pressure environment created within the operating theatre makes the spread of aerosols faster, posing an increased risk of airborne viral transmission. A negative pressure environment is ideal to reduce dissemination of the virus beyond the operating theatre, although such facilities are not widely available. A high frequency of filtered air exchanges may help reduce viral load within an operating theatre [68]. An air exchange equal or more than 25 cycles per hour is sufficient for viral load reduction. This, combined with high-efficiency particulate air filters that exist as a standard in most theatres, reduces the chance of viral dissemination [69].

Screening of elective patients

Screening elective patients is key to not only reduce the risks of horizontal viral transmission but also reduce the increased morbidity and mortality associated with undergoing a surgical procedure while COVID-19-positive. National guidance has been released from NHS England and NICE, as well as tailored gynaecological advice from learned societies [29,70,71].

All patients should be advised to follow comprehensive social distancing and hand hygiene measures, as per UK government guidance, for 14 days before planned admission [71]. Pre-admission hospital attendances should be kept to a minimum. Preoperative assessment and investigations, including bloods tests, MRSA screening and COVID-19 swab testing, should be undertaken during a single visit where possible, to reduce transmission risks.

All patients should undergo SARS-CoV-2 virology screening using standard oropharyngeal and nasal swabs, in keeping with national guidance. Tests should be done from 3 days before admission, in accordance with local-test-result turnaround times. Following testing, all patients should be instructed to self-isolate at home until surgical admission to hospital or be admitted to a hospital and isolated in accordance with local hospital resources and policies.

Patients testing positive for SARS-COV-2 should have surgery deferred for at least 14 days from the onset of symptoms and undergo surgery only when asymptomatic. Advice should be given regarding self-isolation at home for the patient and any household members. Arrangements should be made for retesting (viral clearance) in line with local policies.

On the day of admission, all patients (day case and inpatient) should have their temperature checked and be screened using a screening questionnaire assessing:

- any current symptoms (cough, temperature, loss of taste);
- contact history;
- history of previous exposure and infection of family members; and

- any specific contact from NHS 'test and trace'.

Patients testing negative for SARS-COV-2 but with a temperature of ≥37.7 °C on the day of admission or screening positive on questioning should be considered suspected COVID-19 cases. Advice should be given regarding self-isolation at home. Surgery should be deferred for 14 days and retesting undertaken in line with local policies.

Further tests, including lymphocyte count, ferritin, d-dimers, LDH and CT chest imaging, are not generally required for benign gynaecological surgery but may play a role in high-risk patients and high-risk procedures, such as cardiothoracic surgery.

Following surgery, patients should have daily screening questions and temperature checks until discharge. After discharge, a virtual follow-up consultation should be offered if clinically acceptable. If a patient develops a post-operative pyrexia, arrangements should be made for a virtual or face-to-face clinical review. SARS-CoV-2 retesting should be undertaken if there is no other clear explanation for the pyrexia. All patients being discharged to a care home or a hospice should be tested up to 48 h prior to discharge. A surgical pathway is proposed in Fig. 1.

The organisation

Organisations responsible for patient care need to ensure that surgery remains safe; thus, a number of considerations are essential. Firstly, redeployed staff must be re-assimilated to ensure adequate staffing and the safe running of surgical units. Many staff would have been redeployed to other departments within or outside their hospitals to help fight the COVID-19 pandemic. There is also a need to factor in staff absences related to COVID-19. During the first peak, staff absence ranged from 20.4% to 24.7% in the first 6 weeks of the outbreak and fell to between 9.2% and 13.8% between weeks 7 and 12 worldwide. Where elective surgery was carried out, it was possible to maintain 75% of elective work [72]. The reallocation of facilities is also essential, as many outpatient rooms, waiting areas and theatre spaces were utilised in the expansion of COVID-19-related patient care. It is also essential that there is adequate critical care capacity for high-risk elective patients before routine surgery is recommenced.

It is imperative that separate pathways are in place for both elective and non-elective patients, as well as COVID-19-positive and -negative patients, to protect both patients and staff. This may involve utilising separate floors, buildings or even hospitals, specifically including separate theatres, recovery areas and ward facilities, as well as separate staff groups. 'COVID-19-free' staff should be screened daily using an appropriate questionnaire, as well as undergoing rapid PCR antigen testing if symptomatic. Regular swab testing to ensure that asymptomatic COVID-19 infection is not missed is also recommended, and lateral flow testing is being rolled out NHS-wide. The role of IgG antibody testing in staff screening is currently unknown; however, if coupled with the vaccine, it will likely become a game changer in the fight against COVID-19.

A recent study by Kane et al. highlighted the importance of COVID-19-free surgical pathways and good patient selection [64]. In contrast to the CovidSurg groups' perioperative COVID-19 outcomes, this study demonstrated that only 1.4% (7/535) of patients undergoing urgent elective surgery during a

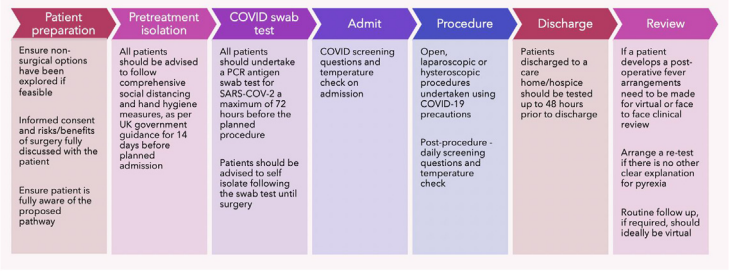

Fig. 1. A proposed surgical pathway.

lockdown period developed SARS-CoV-2, with one post-operative death, even during periods of high community spread of SARS-CoV-2.

COVID-19-free pathways are crucial for patient safety during the COVID-19 pandemic, as they appear to lead to lower SARS-CoV-2 infection rates and complications. Further, preventive measures and patient-level risk assessment will allow surgery to safely continue during this crisis, and future crises. Organisations need to be cognisant of the logistics and safe movement of staff to ensure that their pathways and theatres remain true COVID-19-free zones [73]. The good outcomes obtained in a COVID safe, single site area as highlighted by Kane et al may not be reproducible in centres that do not have such stringent risk mitigation strategies [74].

Infection control practices, including the use of PPE, should comply with local and national protocols. PPE, including water-repellent, long-sleeved surgical gowns, eye and face protection, gloves and FFP3 respirators, are recommended for medical and theatre personnel during surgical procedures conducted under general anaesthesia (GA), to reduce the SARS-CoV-2 transmission risks if the COVID-19 status of the patient is unknown. The decision to wear full PPE in cases where the patient has screened and tested negative should be based on local guidance. The ability to sustain safe gynaecological surgery will also depend on the background COVID-19 infection rate within the community, and there should be predetermined levels at which surgery would be considered unsafe.

The vaccine and the future

The nationwide roll-out of the COVID-19 vaccine is likely to be a pivotal moment in the final push towards fully 'flattening the curve' and allowing services to normalise. There are challenges to a nationwide vaccination programme, and a targeted approach has been deemed essential, with national strategies to combat the transmission of SARS-CoV-19 based on priority groups within the population being vaccinated first. These include frontline medical staff, as this group of workers are not only at increased risk of contracting COVID-19 but also likely to be a source of nosocomial infection [75]. The importance of vaccination is that it may serve to replete the workforce available to combat COVID-19 during the peaks and also allow staff to contribute to the re-establishment of elective surgery after the peaks.

The preoperative vaccination of patients, particularly those who were previously deemed unsuitable for surgery due to their high COVID-19 risks, may be pivotal in the scaling up of the reintroduction of elective surgery and potential reduction of morbidity and mortality [76]. In the long term, widespread vaccination of both patients and clinicians will be key to reducing both transmission and patient morbidity and mortality. Guidelines are already emerging on how surgeons and patients should be cognisant of the side effects of vaccination and how long patients will need to wait before surgery post vaccination [77], so that side effects of the vaccines are not confused with potential complications of surgery.

Summary

It is clear that COVID-19 will continue to test healthcare services for years to come; however, suspending elective surgery at every potential 'peak' is not the long-term answer and will only result in worse backlogs and poor patient experiences and outcomes. Robust surgical pathways must be in place to combat further crises. Patient selection, prioritisation and consent are key to reducing surgical morbidity and mortality and inadvertent transmission. Non-surgical methods of treatment should be explored as a first-line choice, if appropriate; however, if the decision for surgery is made, each patient should undergo an individualised risk assessment. Consent is key, and patients should be aware of the increased surgical risks associated with COVID-19. Green, COVID-19-free surgical sites for elective gynaecological surgery, with regular staff screening, should be established. All surgery undertaken should be done so with the appropriate PPE and in the correct theatre environment. Appropriate COVID-19 precautions should be taken for open, laparoscopic and hysteroscopy surgery. In the long term, vaccination is likely to play a key role in the full restoration of services; however, before all staff and patients can be given the vaccine, priority may be given to particularly vulnerable patients awaiting surgery to further reduce potential risks.

Practice points

- COVID-19 has had a significant impact on gynaecological services, and robust, green, COVID-19-free pathways must be developed to withstand further peaks.
- Despite its remaining a theoretical risk, to date, there is no evidence to suggest COVID-19 is transmissible through surgical smoke plumes.
- There is no clear evidence to advocate the open route over the minimal access route to reduce the risk of COVID-19 transmission.
- Safe surgical technique is essential in reducing the potential risk of COVID-19 transmission.
- Perioperative COVID-19 infection is associated with increased patient morbidity and mortality.
- Screening surgical patients (RT-PCR testing and symptoms questionnaire) is key to both reducing the risks of horizontal viral transmission and the increased morbidity and mortality associated with undergoing a surgical procedure while COVID-19-positive.
- All gynaecological surgeries should be undertaken with the appropriate PPE and in the correct theatre environment.

Research agenda

- Research on psychological and physical sequelae of COVID-19 surgical delays
- Research on the impact of COVID-19 on surgical training
- Conduct comparative studies of COVID-19-free green pathways
- Research on outcomes of patients undergoing gynaecological surgery during COVID-19 times
- Evaluate the impact of the COVID-19 vaccine on the future of surgery within gynaecology

Declaration of competing interest

All authors declare no conflicts of interest.

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