SPECIAL ARTICLE

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Consistency of global recommendations regarding open versus laparoscopic surgery during the COVID-19 pandemic: a systematic review

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Abstract

Background: Throughout the COVID-19 pandemic, there has been worldwide debate regarding whether open surgery should be performed in preference to laparoscopic surgery due to the theoretical higher risk of viral aerosolization by the release of pneumoperitoneum. We aimed to assess the consistency of national and international surgical society recommendations regarding the choice of surgical approach; assess the quality of evidence of viral emission in surgical aerosol; and assess the quality of evidence comparing aerosol generation by different surgical energy devices.

Methods: A systematic review of PubMed, Medline, Embase and Cochrane databases was performed. Three search strategies were employed. Twenty-eight studies were included in the final analysis and quality appraised. Confidence in review findings was assessed using the GRADE-CERQual (Confidence in Evidence from Reviews of Qualitative research) tool.

Results: Worldwide recommendations regarding open versus laparoscopic surgery are consistent, with a majority recommending that surgical approach is decided on a case-by-case, risk minimization approach. There is limited, low-quality evidence that viral particles can be emitted in surgical aerosol. There is a paucity of literature on the quantity of aerosol produced by different surgical energy devices, and no evidence to support the use of certain surgical instruments to minimize aerosol production.

Conclusions: There is considerable consistency among worldwide recommendations regarding the choice of surgical approach, although the evidence base is lacking. To inform clinical recommendations, further research examining viral emission, transmission, infectivity and amount of surgical aerosol produced is required.

Introduction

COVID-19 is transmitted via aerosol. Aerosol is generated during laparoscopy by the creation and release of pneumoperitoneum. Aerosolization also occurs during open surgery, although the extent is unclear especially in relation to various electrosurgical and ultrasonic instruments.

COVID-19 RNA has been detected in respiratory specimens, saliva, blood and stool.[1] In addition, the angiotensin-converting enzyme 2 (ACE2) receptor, a binding site for SARS-CoV-2, is highly expressed in intestinal epithelial cells.[2] While the infectivity of virus in extrapulmonary specimens is unknown, there is a theoretical risk of coronavirus transmission during surgery, via the aerosolization of gastrointestinal contents, blood and other bodily fluids.[3]

However, there is no evidence of coronavirus transmission via aerosol generated during laparoscopic or open surgery. There has been worldwide debate regarding whether open surgery should be performed in preference to laparoscopic surgery due to the theoretical higher risk of viral aerosolization by the release of pneumoperitoneum.

The aims of this qualitative systematic review were to:

(1) Assess the consistency of global recommendations regarding the choice of open versus laparoscopic surgery during the COVID-19 pandemic;

(2) Assess the quality of evidence of viral emission in surgical aerosol; and
(3) Assess the quality of evidence comparing aerosol generation by different surgical energy devices.

Methods

This study was registered with the PROSPERO[4] international prospective register of systematic reviews (registration number: CRD42020186434). Literature searches and article selection was conducted by a single researcher (SJ). Data abstraction, analysis, quality appraisal and confidence in review findings were independently assessed by two researchers (SJ and AH). Findings were collated and disagreements resolved by consulting the senior authors. The Preferred Reporting Items for Systematic Reviews and Meta Analyses[5] (PRISMA) guidelines were followed and PRISMA checklist was completed (Fig. S1). Three search strategies were employed.

Search strategy and eligibility

Choice of open versus laparoscopic surgery during the COVID-19 pandemic

First, a search of PubMed, Medline, Embase and Cochrane databases was undertaken on 17 November 2020. Search terms were ('Coronavirus' OR 'Covid-19' OR 'SARS-CoV-2') AND (('laparoscopy' OR 'minimally invasive surgery') OR ('surgery' AND 'recommendation' OR 'guideline')). Relevant references were searched manually. Second, a targeted web search of grey literature was performed by searching for major surgical society homepages from all major geographical regions of the world, namely North America, Europe, Asia-Pacific, Latin America, Africa and the Middle East. This search was conducted on 17 November 2020, and identified 10 national and international surgical society homepages which were then searched for guidelines or statements regarding the choice of surgical approach during the COVID-19 pandemic.

Articles were included if they were published by a national or international general surgical society and made a recommendation regarding the choice of surgical approach during the coronavirus pandemic. There was no limitation on date or language of publication. If surgical societies had published multiple statements, the most recent was included. Publications unrelated to general surgery, not commenting on choice of surgical approach or citing another surgical society's recommendation were excluded.

Evidence of viral emission in surgically generated aerosol

PubMed, Medline, Embase and Cochrane databases were searched on 18 November 2020. Search terms were 'virus' AND ('surgical smoke' OR 'surgical plume' OR 'surgical aerosol' OR 'surgical vapour'). Studies were included if they examined the presence of any virus in aerosol generated during any human surgery. All study designs were included with no limitation on language or date of publication. Animal studies, laboratory studies and review articles were excluded.

Amount of aerosol generation by type of surgical instrument

PubMed, Medline, Embase and Cochrane databases were searched on 18 November 2020. Search terms were 'instrument' AND ('surgical smoke' OR 'surgical vapour' OR 'surgical plume' or 'surgical aerosol'). Published peer-reviewed articles comparing the amount of surgical smoke produced by two or more surgical instruments were included. All studies (including laboratory and animal experiments) comparing aerosol production were included. There was no limitation on date of publication or language. Review and opinion articles were ineligible.

Data collection and analysis

For surgical society guidelines, date of publication, statement regarding the choice of surgical approach and evidence base were noted. Recommendations for safe surgery were collated and consistency of recommendations was assessed.

For studies examining viral emission in surgical aerosol, date of publication, study design, population, virus and surgery performed were noted. The total number of studies demonstrating viral emission in surgical smoke and percentage of the study population where virus was detected in surgical aerosol was examined.

For studies comparing aerosol generation by surgical instruments, experiment design, results and ranking of instruments producing the most aerosol were reviewed narratively to determine trends.

Quality of guidelines and experimental studies was assessed using the AGREE-II (Appraisal of Guidelines for Research and Evaluation)[6] tool and Johanna Briggs Institute Checklist for non-randomized experimental studies,[7] respectively. Where applicable, confidence in review findings was assessed using the GRADE-CERQual[8] (Confidence in Evidence from Reviews of Qualitative research) tool.

Results

Consistency of global recommendations regarding the choice of open versus laparoscopic surgery

One thousand two hundred and eighteen publications were screened, and inclusion and exclusion criteria applied (Fig. S2). Fourteen guidelines were included in the final qualitative analysis. Table S1 summarizes included guidelines' statement regarding the choice of surgical approach. This includes the evidence base cited by each guideline.[30,44,47,49–57] Table S2 summarizes surgical society recommendations for safe surgery. Quality assessment of guidelines is detailed in Table S3.

There is considerable consistency among worldwide recommendations regarding the choice of open versus laparoscopic surgery. Twelve of 14 guidelines[9–20] recommend that surgical approach is decided on a case-by-case basis. Two guidelines recommend avoiding laparoscopy where coronavirus infection is suspected or confirmed.[21,22]

Evidence of viral emission in aerosol generated during surgery

Nine hundred and twelve studies were screened and inclusion and exclusion criteria applied (Fig. S3). Ten articles were included in

final qualitative synthesis.[23–32] Table S4 summarizes included studies' findings. Quality assessment of included studies is summarized in Table S5.

Our review finds limited evidence on viral particles that are emitted in surgical aerosol. Every study detected the presence of viral DNA rather than intact viral particles, without assessment of their infectivity. In nine studies, viral DNA was detected in surgical aerosol in a percentage of cases. The percentage varied significantly, with viral DNA detected in 16–90% of cases.[23–26,28–32] One study found no viral DNA emission in surgical aerosol.[27]

Viral emission during open surgery was investigated in nine studies.[23–29,31,32] Eight studies demonstrated human papillomavirus (HPV) DNA in surgical aerosol, or on swabs of equipment used to collect aerosol.[23–26,28,29,31,32] Viral emission during laparoscopy was investigated in one study. Hepatitis B DNA was detected in surgical aerosol of 10 out of 11 cases of laparoscopic surgery in patients who were hepatitis B surface antigen positive.[30]

Three studies further examined whether emitted viral DNA was transmitted to the surgeon. A single study by Zhou *et al.* demonstrated HPV DNA transmission to surgeons without subsequent HPV infection.[32] In contrast, Ferenczy *et al.* and Weyandt *et al.* found no evidence of HPV DNA transmission to surgeons, despite HPV detection in surgical aerosol.[24,29]

Aerosol generation by type of surgical instrument

Seven hundred and twenty-two studies were screened and inclusion and exclusion criteria applied (Fig. S4). Four articles were reviewed narratively and summarized in Table S6. Quality assessment is detailed in Table S7.

Our review found no evidence to support the use of one surgical instrument over another to decrease aerosol production. No qualitative synthesis was possible due to heterogeneity of studies. There was insufficient data to demonstrate trends in the amount of aerosol produced by different surgical instruments.

Fitzgerald *et al.* conducted a single-blind controlled study where patients underwent laparoscopic surgery solely using ultrasonic scalpels or diathermy. Intraoperative gas samples were aspirated from the abdomen and analysed for the concentration of six prespecified hydrocarbons. There was a non-significant trend towards lower concentrations of all hydrocarbons with ultrasonic dissection compared to diathermy.[33]

Weld *et al.* compared total particle number concentration after electrosurgical Bipolar Macroforceps (Aesculap, Center Valley, PA, USA), ultrasonic Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, OH, USA), electrosurgical Floating Ball (Tissue Link Medical Inc., Dover, NH, USA) and electrosurgical Monopolar shears (Ethicon Endo-Surgery) were applied to porcine muscle *in vitro*. Each instrument was used at a single setting and activated for a specified time. The Monopolar shears produced the most concentrated aerosol, followed by the Floating Ball (Medtronic, Minneapolis, MN), Harmonic Scalpel and Bipolar Macroforceps.[34]

Two studies measured the degree to which visibility was obstructed by aerosol produced by different surgical instruments. Choi *et al.* randomized 20 patients undergoing laparoscopic hysterectomy by a single operator to the intraoperative use of an ultrasonic scalpel or monopolar cautery. The degree to which aerosol affected visibility was assessed using a Likert scale by two observers. The ultrasonic scalpel created less aerosol and had better laparoscopic visibility than monopolar cautery.[35]

Kim *et al.* utilized image software to determine the percentage of pixels in a videoframe containing aerosol when the ultrasonic Covidien Sonicision (Covidien, Mansfield, MA, USA), ultrasonic Harmonic ACE (Ethicon Endo-Surgery) and ultrasonic Olympus SonoSurg (Olympus, Center Valley, PA, USA) were applied to bovine liver at a specified setting. The most significant differences were observed in the coagulation setting, where the SonoSurg generated negligible aerosol, Sonicision (Medtronic, Minneapolis, MN) generated limited obstruction and Harmonic ACE generated aerosol obstructing one-fourth of the laparoscopic field.[36]

Discussion

Open versus laparoscopic surgery

Current surgical society guidelines are consistent, with a majority recommending that surgical approach is decided on a case-by-case, risk minimization basis. We have moderate confidence in our review finding (Table S8), noting the inherent methodological limitations when qualitatively assessing clinical practice guidelines. Further limitations are the small number of guidelines, lacking an evidence base. Five guidelines from surgical society websites did not undergo peer review, limiting reliability. There is a risk of bias from the targeted web search for surgical society homepages, as there may be surgical society websites that were not screened. Bias may also arise from the lack of geographical representation among included guidelines.

At the outset of the coronavirus pandemic, surgical societies rapidly produced guidelines discouraging laparoscopy. Guidelines have been updated and become progressively nuanced; presently, recommending surgical approach is decided on a case-by-case basis with risk minimization strategies employed. Guidelines are limited to expert opinion or consensus statements erring on the side of caution. Laparoscopy has been reintroduced and there is no evidence of coronavirus transmission via aerosol generated in open or laparoscopic surgery. In addition, there was no evidence of disease transmission via surgical aerosol in other coronavirus outbreaks such as severe acute respiratory syndrome or Middle East respiratory syndrome.[3]

When operating on a patient with suspected COVID-19, it is unclear whether aerosolization of blood, faeces and other bodily fluids has the same infective potential as respiratory tract aerosols. In a study of the biodistribution of SARS-CoV-2 in patients with COVID-19, lower respiratory tract samples were most frequently positive for the virus; however, live SARS-CoV-2 was detected in faecal specimens, indicating faecal transmission was possible.[1]

While risk mitigation strategies published by surgical societies are precautionary, they are not evidence based. They do not consider the availability of resources such as negative-pressure rooms in developing countries, limiting utility. In response, surgeons have suggested low cost alternatives such as exhaust fans in theatres to generate negative pressure to mitigate risk.[37]

Our review finding is concordant with other reviews on choice of surgical approach during the coronavirus pandemic. Reviews by Mowbray *et al.* and Tivey *et al.* concluded there was no evidence that laparoscopy posed a greater infection risk than open surgery, however precautionary measures should be implemented.[38,39]

Factors to consider when deciding surgical approach include local epidemiology of COVID-19, surgical expertise, equipment availability and advantages and disadvantages of each approach to patients and staff. Advantages of laparoscopy include clear intraoperative tissue display, decreased morbidity and decreased length of stay.[40] A statistical model published by Elliot *et al.* found that decreased length of stay with laparoscopy was associated with a reduced risk of nosocomial perioperative SARS-CoV-2 infection and mortality.[41] Another consideration is that physical barriers in laparoscopy may contain and reduce exposure to aerosol generated by surgical power instruments.[3] Disadvantages of laparoscopy include longer duration of surgery and anaesthesia and respiratory issues such as decreased lung volume, increased airway pressure and carbon dioxide retention.[42]

While outside this reviews' scope, there has been a paradigm shift towards non-operative management. This is partially because patients with perioperative SARS-CoV-2 infection have poor surgical outcomes. An international multicentre cohort study noted that post-operative pulmonary complications occurred in half of the patients with a perioperative SARS-CoV-2 infection and that there was a 23.8% all-cause 30-day mortality rate.[43]

Emission of viral particles in surgical aerosol

There is evidence that viral components can be emitted in surgical aerosol, however, evidence is limited and low-quality. We have very low confidence as this finding is applicable to the phenomenon of interest (Table S8). The main limitation is that studies examined the emission of HPV and hepatitis B virus DNA in surgical aerosol. Findings are not generalizable to patients with COVID-19, as their transmission mechanisms, namely skin-to-skin contact and via body fluids, differ from the transmission mechanism of SARS-CoV-2 which is spread by aerosol. Additional limitations were small sample sizes and lack of randomization or control groups. Outcomes were only measured once, and sensitivity of equipment to detect viral DNA was not described. There was considerable heterogeneity in patient populations, procedures and methods for measuring viral particles in aerosol.

Importantly, there is no evidence for infectivity of such viral emissions, even in studies which examined the transmission of viral DNA to operators.[24,29,32] There are no studies with long-term follow-up assessing if exposure to virus-containing surgical aerosol causes disease. This limits the validity of applying these findings to recommend a change to current surgical practice by uniformly avoiding laparoscopy. It is postulated that high temperatures of surgical power instruments inactivate the virus.[44]

Aerosol generation by type of surgical instrument

The major limitation of this review was the paucity of studies comparing aerosol production by different surgical instruments. Studies were low quality. Sample sizes were small, and outcomes were not measured repeatedly or reliably.

Across the literature, the terms surgical smoke, plume, vapour and aerosol are used interchangeably to describe gaseous by-products of energy-based surgical instruments.[34,45] Surgical aerosol is made up of 95% water, and 5% cellular debris including gaseous hydrocarbons, blood and tissue particles as well as viruses and bacteria.[46]

The mechanism of aerosol generation by different instruments determines the resulting particle size distribution. Electrosurgical devices and lasers produce aerosol by heating tissue past its boiling point causing the rupture of cell membranes and release of a water-based vapour.[47] Small spherical particles are produced by uniform drying of liquid droplets in gas.[34] Ultrasonic scalpels produce a low temperature vapour by compressing tissue on a rapidly oscillating plate[33] and larger particles result from the explosion and fragmentation of tissue.[34] Electrocautery generates particles with the smallest average aerodynamic size, while ultrasonic scalpels produce particles with the largest average size.[33,34]

The size distribution of particles determines the distances particles travel, the time particles persists in air and effectiveness of personal protective equipment.[48] Additional factors influencing the amount of aerosol produced by surgical instruments include instrument power and activity setting (cutting or coagulating), length of time the instrument is activated and tissue type.

Directions for future research

An evidence base is required for future recommendations regarding the choice of surgical approach during the COVID-19 pandemic. A prospective observational cohort study is required to determine if SARS-CoV-2 can be emitted in surgical aerosol. Operating room air samples from patients with COVID-19 undergoing any surgery could be analysed for SARS-CoV-2. Quantitative polymerase chain reaction analysis can compare the amount, if any, of SARS-CoV-2 emitted during open or laparoscopic surgery. Patient outcomes can also be compared. Randomization is not feasible as there are many other patient- and disease-related factors that influence surgical approach. Infectivity of emitted viral particles could be determined by further experiments on human cell lines or animals. Aerosol generation by different surgical instruments can be reliably measured and compared by laser particle sensors, transmission electron microscopy or gas chromatography. These experiments are best performed in a laboratory.

Conclusions

Global recommendations regarding the choice of open versus laparoscopic surgery are consistent, with a majority of surgical society guidelines recommending surgical approach is decided on a case-by-case basis. These recommendations are not evidence based. While there is limited evidence demonstrating viral emission in surgical aerosol, there is no evidence to support or refute the infectivity of these viral components. There is a paucity of literature quantifying and comparing aerosol production by different surgical instruments. This review highlights significant knowledge gaps and further studies are required to inform clinical recommendations.

Conflicts of interest

None declared.

Author contributions

Susan Jacob: Data curation; investigation; methodology; writing-original draft. **Ahmer Hameed:** Data curation; writing-review & editing. **Vincent Lam:** Conceptualization; writing-review & editing. **Tony Pang:** Conceptualization; writing-review & editing.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1. PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses) checklist.
Figure S2. PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses) diagram of national and international surgical society guidelines regarding the choice of open or laparoscopic surgery during the COVID-19 pandemic.
Figure S3. PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses) diagram of studies examining viral emission in surgical aerosol.
Figure S4. PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses) diagram of studies comparing aerosol generation by different surgical instruments.
Table S1. Summary of national and international surgical society recommendations regarding the choice of open versus laparoscopic surgery during the COVID-19 pandemic.
Table S2. Summary of national and international surgical society recommendations for safe surgery.
Table S3. AGREE II (Appraisal of Guidelines for Research and Evaluation) appraisal of included national and international surgical society guidelines regarding the choice of open versus laparoscopic surgery during the COVID-19 pandemic.
Table S4. Summary of studies examining viral emission in surgical aerosol.
Table S5. Johanna Briggs Institute Critical Appraisal Checklist for non-randomized experimental studies for included studies examining viral emission in surgical aerosol.
Table S6. Summary of studies comparing aerosol production by different surgical instruments.
Table S7. Johanna Briggs Institute Critical Appraisal Checklist for non-randomized experimental studies for included studies comparing the amount of aerosol generated by different surgical instruments.
Table S8. GRADE-CERQual (Confidence in Evidence from Reviews of Qualitative research) assessment of review findings.