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Assessing the risk of viral infection from gases and plumes during intra-abdominal surgery: a systematic scoping review

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Abstract

Background: The aim of this study was to identify the current evidence regarding the risk of acquiring viral infections from gases or plumes during intra-abdominal surgery. Peritoneal fluids may contain cellular material and virus particles. Electrocautery smoke and plumes from energy devices may aerosolize harmful substances and viral particles. Insufflation and desufflation during laparoscopic surgery may also aerosolize and distribute biological material. A systematic scoping review was performed to assess the evidence and inform safe surgical practice.

Methods: A systematic search of the PubMed and Medline databases was undertaken until June 2020, observing Preferred Reporting Items for Systematic Reviews and Meta-Analyses methodology, to identify articles associating viral infection of operating room staff from surgical gases and plumes. All evidence levels were included. The search strategy utilized the search terms 'surgery', 'laparoscopy', 'laparoscopic' 'virus', 'smoke', 'risk', 'infection'.

Results: The literature search identified 74 articles. Eight articles relevant to the subject of this review were included in the analysis, two of which specifically related to intra-abdominal surgery. Of the remaining six, four involved gynaecological surgery and two were *in-vitro* studies. No evidence that intra-abdominal surgery was associated with an increased risk of acquiring viral infections from exsufflated gas or smoke plumes was identified.

Conclusion: There is currently no evidence that respiratory viruses can be found in the peritoneal fluid. Whilst there is currently no evidence that desufflated carbon dioxide or surgical smoke plumes present a significant infectious risk, there is not a wealth of literature to inform current practice. Further clinical research in this area is required.

Introduction

The COVID-19 pandemic has created unprecedented challenges for the global health community. In the midst of the crisis, non-urgent elective surgical operations have been cancelled and extensive preparations have been made to perform operations on patients who are suspected or proven to have contracted the virus.[1] As of April 2020, The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), The Royal College of Surgeons (UK) and the Royal Australasian College of Surgeons have issued statements designed to protect the surgical workforce, and ensure that patients with surgical emergencies or time-critical surgical problems are able to access safe, evidence-based and high-quality surgery during the COVID-19 pandemic.[2–4] The imperative remains to provide the same best-practice surgery undertaken pre-pandemic, in terms of caseload, technical approach and patient outcomes.

The risk of acquiring viral infections from surgical gases and plumes during intra-abdominal surgery is unclear. The risk profile comparing open to laparoscopic approaches is also uncertain. It is not clear whether viruses that primarily affect the respiratory system are also shed into the peritoneal cavity; and if so, whether there is a risk that laparoscopic insufflation–desufflation under standard pressures increases the aerosolization and dissemination of infectious material in the operating theatre. This may lead to clinicians opting for open surgery over laparoscopic approaches, which in turn may have implications regarding complications and hospital length of stay.[5]

It is important that decisions made about operating theatre policies, personal protective equipment and the safety of laparoscopic approaches for intra-abdominal surgery is based on evidence. Therefore, the aim of this systematic scoping review was to identify and map the current evidence regarding the risk surgical gases and plumes during intra-abdominal surgery to act as a vector for viral transmission. This review intends to clarify the nature of the existing evidence, to better inform current practice, future planning and further research in the area.

Methods

This manuscript was prepared in conjunction with Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement for scoping reviews. Following pilot testing, a systematic search of PubMed and Medline was undertaken for studies up to June 2020, with screening completed by two investigators. The search incorporated key words including 'virus', 'surgical smoke', 'aerosol', 'diathermy', 'electrocautery', 'laparoscopy', 'laparoscopic' and 'open surgery'. The reference lists of all studies identified by the initial search were examined to locate any potential additional studies.

All studies that investigated the presence, identification or infectivity of virus or viral particles in the peritoneal cavity or in surgical smoke plumes, including those from human tissue, the peritoneal cavity, and gastrointestinal, biliary or urogenital tracts were included. All types of publications, of any language, with primary data on the study question were eligible. Studies that reported outcomes for transmission of cells and particles other than virus during intra-abdominal surgery, did not report data on infection risk associated with intra-abdominal surgery separately from other types of surgery, or not published or adequately translated into English were excluded.

The initial searches were performed by one author (JT), which was verified independently by another author (BDW). All abstracts and full-text articles were considered for eligibility by two authors (DJG, BDW). Discrepancies were discussed and resolved by consensus. Data were extracted into predefined tables. Study quality and level of evidence were not formally assessed.

With regards to terminology, we refer to the viral agent as the SARS-CoV-2 virus, whereas the clinical syndrome and pandemic are referred to as COVID-19.

Results

The initial literature search identified 933 articles; 859 were excluded on initial screening of titles and abstracts. Of the 74 remaining articles, 72 were published originally in English, one in Mandarin/Cantonese and one in German. The PRIMSA flow diagram is shown in Figure 1. Eight articles that specifically assessed viral transmission from electrosurgical techniques or were related to intra-abdominal surgery were included in the final analysis (Table 1).

Two studies were specific to intra-abdominal surgery. One reported on patients who underwent robotic and laparoscopic surgery, and the other was a case report of Ebola transmission during laparotomy.[6,7] The remaining six studies involved the collection of aerosols generated from gynaecological procedures (n = 4), and virus-infected cells tested *in vitro* (n = 2).

In the only study investigating potential viral transmission during abdominal surgery, Kwak *et al.*[6] collected surgical smoke during 11 robotic and laparoscopic procedures of hepatitis B virus (HBV)-positive patients of at least one-hour duration, with five cases of robotic or laparoscopic colorectal surgery, three cases of laparoscopic gastrectomy and three cases of laparoscopic hepatic wedge resections. HBV deoxyribonucleic acid (DNA) was detected in surgical smoke in 91% of cases (10/11), suggesting that HBV may be transmitted via aerosols during abdominal surgery.

Similarly, the case report by Khan *et al.*[7] describes the transmission of Ebola virus from a patient with suspected abdominal perforation to 13 health-care workers during laparotomy in the Democratic Republic of Congo.

The studies involving gynaecological procedures revealed largely similar results. Sood *et al.*[8] collected smoke plumes from 49 patients undergoing loop electrosurgical excision procedure (LEEP) for cervical intraepithelial neoplasia and reported the presence of HPV DNA in 37% of the smoke filters. In a similar study, Neumann *et al.*[9] found HPV DNA in 16.7% of smoke plumes from LEEP for high grade squamous intraepithelial lesions of cervix. However, the potential to cause human infection was unclear in both studies.

Sawchuk *et al.*[10] determined 57% (4/7) of smoke plume samples collected from the electrosurgical treatment of genital warts contained HPV DNA. Similar findings were demonstrated by Bergbrant *et al.*,[11] with HPV DNA isolated from the nasolabial folds and nostrils of operators in 31.6% and 15.8%, respectively. This was also the only study to assess infective potential of aerosolised viral particles, demonstrating the transmission of infectious BPV particles from surgical plumes.

Conflicting results were obtained from the *in-vitro* studies. Stephenson *et al.*[12] showed that viable P22 bacteriophage could be transferred through aerosols by using electrocautery on a P22-inoculated agarose growth media. On the contrary, Johnson *et al.*[13] did not detect HIV-1 in aerosol generated from electrocautery to fresh human tissue samples.

Discussion

This scoping review assessed the literature for evidence regarding the risk of acquiring viral infection from surgical gases and plumes during intra-abdominal surgery. We identified eight relevant articles from the literature, of which one prospective cohort study[6] and one case report[7] specifically related to intra-abdominal surgery were identified. This study highlights that there is a paucity of high-quality evidence available specifically regarding the infectious risk of viral particles in the peritoneum and during intra-abdominal surgery. Further, there have been no studies that have conclusively demonstrated a risk of infection from aerosolised peritoneal fluid or diathermy smoke plumes.

The only study that investigated the risk of viral transmission during intra-abdominal surgery reported the detection of HBV DNA in 91% of surgical smoke samples collected.[6] These laparoscopic or robotic operations were performed on known HBV

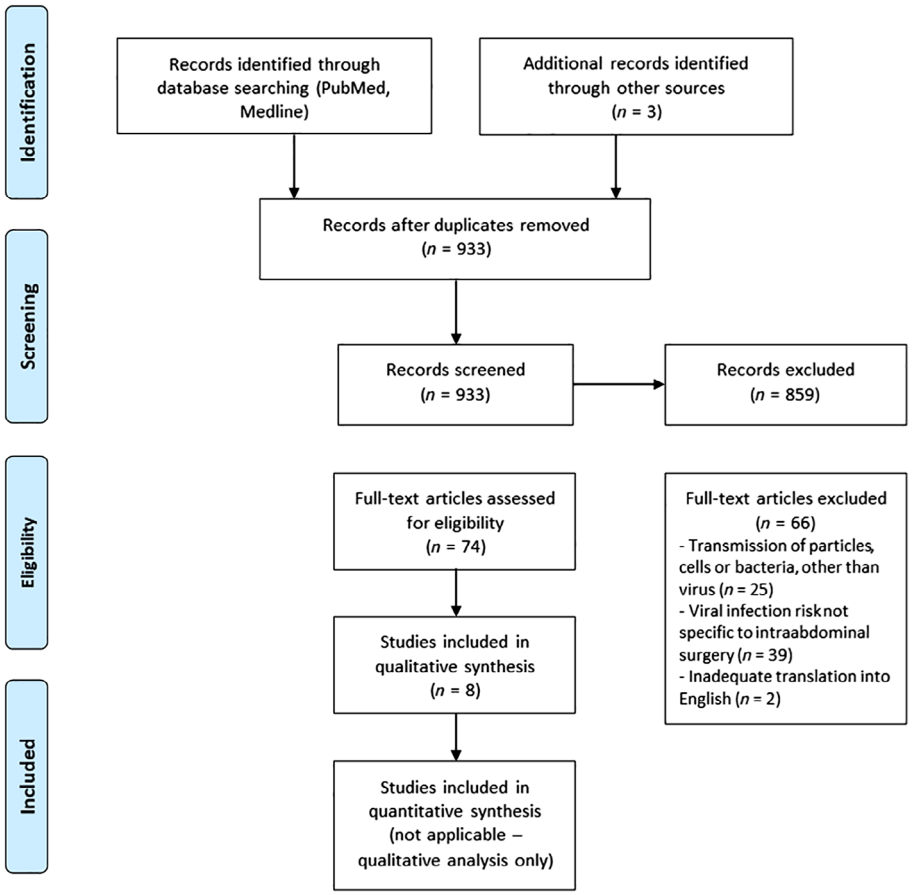

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

positive patients. A single article related to open abdominal surgery was a case report of the likely transmission of Ebola virus from patient to health-care staff after laparotomy for an acute abdomen in the Democratic Republic of Congo.[7] Animal studies have shown transmission of Ebola virus through aerosols,[14] a finding yet to be demonstrated convincingly in humans.[7] Despite this, aerosol-generating procedures are still thought to confer increased risk of human-to-human transmission,[15] as reported by Khan *et al.*[7]

Most studies investigating the risk of intra-operative viral transmission have been focused on the treatment of genital papillomas and cervical malignancy. LEEP is commonly performed for the diagnosis and treatment of uterine cervical lesions. The studies reported in this review detected HPV in surgical smoke in 16.7–37.0% of cases during electrocautery treatment of cervical neoplasia.[8,9] Similarly, studies focusing on the treatment of genital papillomas detected HPV DNA in surgical smoke and on operating personnel in up to 57% of cases.[10,11] This was further supported by one *in-vitro* study which demonstrated transfer of viable bacteriophage within electrocautery smoke.[12] On the contrary, the *in-vitro* study by Johnson *et al.*[13] did not demonstrate the presence of HIV-1 in surgical smoke.

There is an abundance of literature regarding the potential for aerosolization of viral particles from CO_2 laser treatment of warts and upper airway papillomas. CO_2 laser treatment produces larger particles than electrocautery (0.31 versus 0.07 μm, respectively), which is of greater relevance to viral transmission.[16] There is conflicting evidence for the presence of HPV DNA in CO_2 laser vapour generated during the treatment of anogenital warts[17–19] and laryngeal papillomas,[20,21] despite case studies reporting transmission of HPV infection to operating room staff.[16,22] However, infectivity by laser plume containing bovine papillomavirus was demonstrated by the development of cutaneous tumours after inoculation of calves with BPV obtained from laser smoke plume.[23] Although laser techniques have been utilized in urological and gynaecological procedures,[24,25] it has no routine use in intra-abdominal surgery.

This conflicting evidence raises the concern for transmission of SARS-CoV-2 during intra-abdominal procedures. SARS-CoV-2 has been isolated from the airways, upper and lower gastrointestinal canal, respiratory secretions, blood, bile and faecal matter.[26–28] Wang *et al.*[27] identified, using electron microscopy, 'live' SARS-CoV-2 in polymerase chain reaction-positive stool samples of five patients, suggesting potential for faecal transmission. On the contrary, Wolfel *et al.*[28] did not identify infectious virus from stool samples despite high SARS-CoV-2 ribonucleic acid concentrations. To date, SARS-CoV-2 has not been isolated from peritoneal fluid, cerebrospinal fluid or urine.

HBV was reported to be present in surgical smoke produced during laparoscopic and robotic intra-abdominal surgery.[6] It is worth noting that HBV is relatively robust and may better survive electrosurgical temperatures than members of the coronavirus family, with

Table 1 Articles included in final analysis

Author	Year	Country of origin	Study design	Study population	Procedure performed	*n* total	Outcome
Kwak *et al.*[6]	2016	Korea	Prospective observational study	Hepatitis B positive patients	Robotic and laparoscopic abdominal surgery. Collection of surgical smoke and analysis with PCR	11 patients	HBV DNA detected in smoke of 10/11 cases
Khan *et al.*[7]	1995	United States of America	Case report	Patient undergoing laparotomy and health-care workers with direct contact in Democratic Republic of Congo. Health-care workers subsequently developed febrile illness	Laparotomy and appendicectomy for acute abdomen Re-look laparotomy demonstrating diffuse intra-abdominal bleeding Patient later diagnosed to have Ebola haemorrhagic fever	14 subjects (1 patient, 13 health-care workers)	All 14 subjects tested positive to Ebola virus
Sood *et al.*[8]	1994	USA	Quasi-experimental study	Patients with CIN grade II or III	LEEP performed, surgical smoke collected via filter on suction tubing, PCR performed for HPV DNA	49 patients	HPV DNA was detected in 37% (18/49) of smoke filters
Neumann *et al.*[9]	2017	Germany	Prospective observational study	Patients with HSIL cervix	LEEP performed, surgical smoke collected and analysed for HPV	24 patients	High-risk HPV detected in surgical smoke of 4/24 cases
Sawchuk *et al.*[10]	1989	USA	Quasi-experimental study	Patients with human plantar warts. Infectivity assay performed with bovine warts (as infectivity assay not available for HPV)	Half of each human wart was treated with CO_2 laser and the other half treated with electrocoagulation. Vapour collected using a vacuum device and analysed for HPV DNA. Bovine wart treated as per human warts, with vapour collected and solubilized. Infectivity tested via ability to induce focal transformation of mouse C127 cells	8 patients (7 samples for electrocoagulation as DNA lost during one procedure, 8 samples for CO_2 laser)	5/8 CO_2 laser-derived plumes were positive for HPV DNA. 4/7 electrocoagulation-derived samples were positive for HPV DNA. CO_2 laser produced more infective BPV particles than electrocoagulation
Bergbrant *et al.*[11]	1994	Sweden	Quasi-experimental study	Patients with genital warts	CO_2 laser (11 patients) or electrocautery (19 patients). Swabs taken from nasolabial fold/nostrils/ conjunctivae of operators	30 patients	Electrosurgery group: HPV DNA found on 6/19 of nasolabial folds (2/19 positive pre-operatively), 3/19 in nostrils, 0/13 in conjunctivae Laser group: HPV DNA on 3/11 nasolabial folds (2/11 positive pre-operatively), 3/11 in nostrils (all positive pre-operatively) and 0/6 in conjunctivae
Stephenson *et al.*[12]	2004	USA	Quasi-experimental study	Growth media inoculated with a P22 bacteriophage	Electrocautery to growth media, collection of smoke into solution and inoculation of Petri dish with solution	3 samples run	Quantifiable levels of P22 bacteriophage in inoculated growth media from all three samples suggests transmission via aerosols
Johnson *et al.*[13]	1991	United States of America	Quasi-experimental study	HIV-1 infected human blood samples	Electrocautery (cutting or coagulation), bone-cutting router, bone saw and syringe irrigator to blood samples and collection of smoke generated. Cells tested for HIV-1 core antigen with ELISA	12 runs for electrocautery, 9 runs for router, 4 runs for bone saw, 2 runs for irrigator	HIV-1 DNA not detected in any electrocautery samples, but detected in 5/9 router samples, 1/4 bone saw samples, and none in irrigator samples

BPV, *Bovine papillomavirus*; CIN, cervical intraepithelial neoplasia; HBV, hepatitis B virus; HIV-1, human immunodeficiency virus-1; HPV, human papillomavirus; HSIL, high-grade squamous intraepithelial lesion; LEEP, loop electrosurgical excision procedure; PCR, polymerase chain reaction.

a previous study demonstrating that SARS-CoV-1 lost infectivity after heating at 56°C for 15 min.[29] Therefore, specific implications for SARS-CoV-2 remain unclear.

Despite this paucity of evidence, there is concern regarding the theoretical risk of viral transmission during abdominal surgery. Both open and laparoscopic procedures generate aerosolised particles, with some evidence that laparoscopic procedures produce higher concentrations of particles with electrocautery than open techniques.[30] In addition, the issue of increased aerosol generation during the establishment and exsufflation of artificial pneumoperitoneum has also been raised.[31]

The most recent guideline from the SAGES suggests that strong consideration be given to the potential for viral transmission during surgery, but concedes there is little to no evidence regarding the risk of transmission during minimally invasive surgery.[2] Similarly, the 'Intercollegiate General Surgery Guidance on COVID' statement suggests that laparoscopic surgery should only be considered in select patients where the benefit of a minimally invasive approach outweighs the risk of viral transmission.[32]

This presents a dilemma for surgeons and their patients. Considering the potential for increased risk of viral transmission during laparoscopic procedures, clinicians may modify their usual operative approaches. This may inadvertently affect patient outcomes and increase hospital length of stay during a time where exposure to hospital environments should be limited,[33] a view also supported by the SAGES guidelines.[2]

Recent recommendations suggest that the optimal surgical approach is one that will be completed in the shortest time possible and one that is most familiar to the clinician.[31] This view is supported by authors from China and Italy, who suggest that extra precautions should be taken peri- and intra-operatively to reduce transmission risk during laparoscopic surgery rather than abandon it altogether.[1]

This scoping review has some limitations. Scoping reviews are not intended to make judgements of the quality of evidence presented, which makes it difficult to draw generalisable conclusions and inform direct changes in clinical practice. There were no studies that directly addressed the risk of SARS-CoV-2 transmission from surgical gases and plumes, and therefore it is not possible to address this specific concern based on primary evidence.

Conclusions

This review highlights a lack of evidence regarding the risk of acquiring respiratory viral infections from surgical gases or plumes during laparoscopic or open intra-abdominal operations. If this is not addressed, there will be ongoing concerns regarding the risks of performing abdominal surgery on patients who are suspected or proven COVID-19 positive both now and in the future. Further research must be conducted to determine if SARS-CoV-2 is present in peritoneal fluid and if it is able to be aerosolised during operations.

Conflicts of interest

None declared.

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