BJU Int 2020 doi:10.1111/bju.15247

BJUI
BJU International

Original Article

Intraoperative aerosol viral transmission in minimally invasive surgery: a scoping review and impact on clinical guidelines and practice during the onset of the coronavirus disease 2019 (COVID-19) pandemic

Dong-Ho Mun[1], Benjamin Pradere[1,2], Shahrokh F. Shariat[1,3,4,5,6,7,8,9] and Mesut Remzi[1,10]

[1]Department of Urology, Medical University of Vienna, Vienna, Austria, [2]Department of Urology, CHRU Tours, Francois Rabelais University, Tours, France, [3]Institute for Urology and Reproductive Health, I.M. Sechenov First Moscow State Medical University, Moscow, Russia, [4]Department of Urology, Weill Cornell Medical College, New York, NY, USA, [5]Department of Urology, University of Texas Southwestern, Dallas, TX, [6]Karl Landsteiner Institute of Urology and Andrology, Vienna, Austria, [7]Department of Urology, Second Faculty of Medicine, Charles University, Prague, Czech Republic, [8]Division of Urology, Department of Special Surgery, Jordan University Hospital, The University of Jordan, Amman, Jordan, [9]European Association of Urology Research Foundation, Arnhem, The Netherlands, and [10]Chairman of the Laparoscopic and Robotic Surgery Section of the Austrian Urological Association, Vienna, Austria

Objective

To identify the available evidence on aerosol viral transmission risk during minimally invasive surgery (MIS) and evaluate its impact on guidelines development and clinical activity worldwide during the coronavirus disease 2019 (COVID-19) pandemic.

Methods

We performed a scoping review on PubMed, Cochrane, the Excerpta Medica dataBASE (EMBASE), Clinical Trial Register, and the Grey Literature Repository databases, to identify reports on viral transmission via surgical smoke or aerosolisation. A systematic review of all available national and international guidelines was also performed to report their recommendations. Additionally, a worldwide transdisciplinary survey was performed to capture the actual compliance to dedicated guidelines and their impact on MIS activity.

Results

Based on a selection of 17 studies, there was no evidence to support the concerns of an intraoperative viral transmission via pneumoperitoneum aerosolisation. Most national surgical and urological societies either did address this topic or referred to international guidelines. The guidelines of the American College of Surgery, the Royal College of Surgeons, and the European Association of Urology Robotic Urology Section, recommended an avoidance of MIS due to an increased risk of intraoperative aerosol-enhanced transmission. The results of the survey completed by 334 respondents, from different surgical abdominal specialties, suggested a lack of compliance with the guidelines.

Conclusion

There seems to be a dissonance between contemporary guidelines and ongoing surgical activity, possibly due to the perceived lack of evidence. Recommendations regarding changes in clinical practice should be based on the best available research evidence and experience. A scoping review of the evidence and an assessment of the benefits and harms together with a survey showed that laparoscopic procedures do not seem to increase the risk of viral transmission. Nevertheless, the few publications and low quality of existing evidence limits the validity of the review.

Keywords

COVID-19, SARS-CoV-2, minimally invasive surgery, intraoperative viral transmission, surgical smoke, aerosol, #Urology, #COVID19, #COVID, #Coronavirus

Introduction

The onset of the coronavirus disease 2019 (COVID-19) pandemic compelled the healthcare community to reorganise and reallocate resources leading to a reduction and prioritisation of surgical activities worldwide. As part of this, concerns were raised regarding the potentially increased risk of transmission with pneumoperitoneum during minimally invasive surgery (MIS). This concern was based on data suggesting significant quantities of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in stool [1] and gastrointestinal mucosa, [2] together with limited evidence showing an increased exposure of the operating theatre staff to particle concentrations in the surgical smoke/aerosol arising from the pneumoperitoneum [3,4].

The rationale behind the increased risk of intraoperative SARS-CoV-2 transmission is supported by some reports detecting HIV [5,6], hepatitis B virus (HBV) [7] and human papilloma virus (HPV) [8,9] in surgical smoke. Additionally, surgical smoke and aerosolisation are considered as biohazard [10–12] and surgical smoke safety guidelines are already widely available and implemented [13,14]. Recently, Wang and Du [15] confirmed that SARS-CoV-2, similarly to other virus species (such as SARS-CoV-1 [16], Middle East respiratory syndrome [MERS]-CoV [17], influenza A virus H1N1 [18], respiratory syncytial virus [RSV] [19]), can potentially be spread via aerosol. With the unknowns of the evolving crisis, learned societies such as medical associations have adopted the precautionary principle. Indeed, international organisations and leading medical societies released guidelines and cautions regarding surgical activities. Almost all recommended a postponement of elective surgical procedures and the use of risk-stratification strategies [20] to prioritise cases in order to protect resources, while ensuring adequate healthcare provision. Despite a lack of evidence and clinical experience, debates on the safety of MIS have arisen. This has led to the deviation from the standard of care that was established based on strong evidence and value judgements regarding benefits and harms. This deviation from the established guideline methodology has led to recommendations based on low-quality evidence.

In this context, our objective in the present study was: (i) to evaluate the risk of intraoperative aerosol viral transmission by performing a scoping review of the literature, (ii) to review the contemporary COVID-19 guidelines on MIS, and (iii) to evaluate the adherence of surgeons to modified COVID-19 guidelines.

Methods

Evidence Acquisition

Inclusion and Exclusion Criteria

Studies were included if they investigated the presence and infectiousness of viruses or viral DNA in surgical smoke or aerosols obtained from surgical interventions. We excluded reviews, editorials, letters, meeting abstracts, and replies from authors. Only articles in English were included and no restrictions regarding the publication period was made.

Search Strategy

We performed a scoping review according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [21].

To identify reports on viral transmission via surgical smoke or aerosolisation, the PubMed and Cochrane databases were searched on the 30 April 2020. Then, the Excerpta Medica dataBASE (EMBASE), Clinical Trial Register, and Grey Literature Repository databases were searched on the 12 July 2020. The keywords used in our search strategy were (surgical smoke OR (aerosol AND surgery)) AND (virus OR viral). Additional studies of interest were identified from the references of the included reports. Owing to the anticipated heterogeneity across studies, only a narrative synthesis was planned. A detailed search strategy is provided in the supplementary material (Appendix S1).

Study Selection

An initial screening based on study titles and abstracts was performed independently by two investigators (B.P. and D.M.) to assess the eligibility of the articles and implement transparent, reproducible, and valid exclusion criteria. In the event of duplicate articles, we chose the more recent or higher quality article. A full-text revision of potentially appropriate reports was performed after the data extraction process. In case of a disagreement, the issue was solved via consensus or with the help of a co-investigator (M.R.).

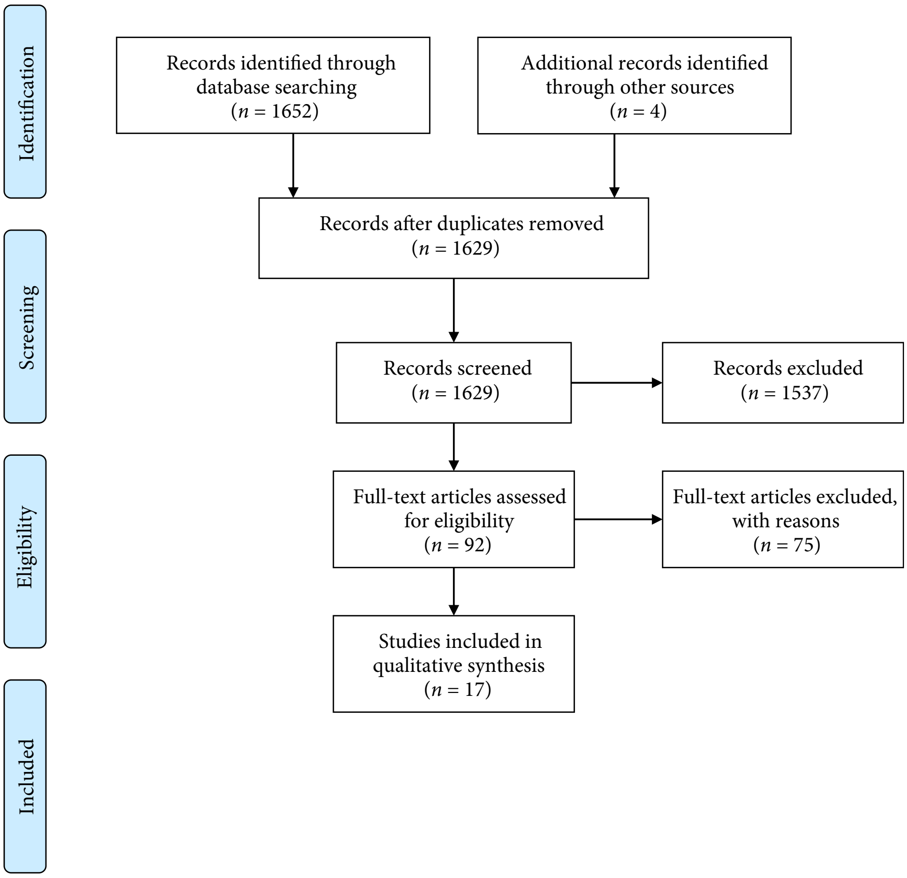
Data Extraction

The following information was extracted from the included articles: first author's name, publication year, country, type of virus, type of intervention, number of patients/samples, study design and methods, measured outcome, results, and conclusions.

Quality Assessment

The Newcastle–Ottawa Scale (NOS) [22] was used to assess the quality of the included studies. The following three factors are rated: 'Selection' (maximum four stars), 'Comparability' (maximum two stars) and 'Outcome' (maximum three stars), with total scores ranging from zero (lowest) to nine (highest). Studies with scores of more than six stars were identified as 'high quality'.

Fig. 1 The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow chart for article selection process.



Guideline Screening

The homepage WORLDOMETERS [23] was accessed on 4 April 2020 and countries with a total of >2000 COVID-19 cases were included. The Internet presence of the respective surgical association and urological association were screened for guidelines and recommendations regarding risk-stratification and surgical approach (open surgery vs MIS). Additionally, published guidelines of leading surgical and urological societies were screened and summarised.

Survey

Simultaneously, in order to measure the impact of COVID-19 on the surgical activity worldwide, a 15-item, cross-sectional web-based survey created with Google Forms in the English language according to the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) [24] was disseminated on 13 April 2020 (Appendix S2). Colleagues who specialise in primarily surgical professions including general surgery, gynaecology, and urology were invited via e-mail or social media to participate.

Results

Evidence Synthesis

Study Selection and Characteristics

The selection process according to PRISMA is shown in Fig. 1 and the PRISMA checklist is provided in the supplementary materials (Appendix S3). From the initially identified 1652 articles, 1629 remained after elimination of duplicates. After screening titles and abstracts, 92 potentially relevant publications underwent full-text review. In total, 17 articles were selected for the scoping review according to the selection criteria. All included reports were published between 1990 and 2020 and mostly had an experimental design. In all, 11 studies were from the USA, two from Germany, one from South Korea, one from Sweden, one from China, and one from Thailand.

Intraoperative Viral Transmission

The 17 included studies are listed in Table 1. The current published literature on intraoperative viral transmission is extremely limited and mostly published before 2010. Most of the reports on viral transmission in surgery examine the transmission of HPV during surgical treatment of condylomata acuminata by CO_2 laser or electrocoagulation. In total, 11 publications on HPV were reviewed. Several articles report the detection of HPV in surgical laser plume [25–28], suction filters [29] or surgeon tissue swabs [9]. In contrast, Subbarayan *et al.* [30] reported no presence of HPV 16 DNA in surgical smoke caused by electrocautery in human and a mouse model. Furthermore, another group demonstrated that no viable virus from laser plume particles could be cultured and showed no signs of viral infection when admitted to susceptible cell lines [31]. In addition, Capizzi *et al.* [32] detected no presence of viral pathogen in 13 patients undergoing CO_2 laser resurfacing. Likewise, further studies suggested that there was no solid evidence for intraoperative viral transmission [8,33]. In contrast, Best *et al.* [34] recently reported in an animal model a 100% penetrance rate of mouse papillomavirus after exposure of uninfected mice with surgical smoke from treated mouse papillomavirus tail warts.

The evaluation of spreading during laparoscopic surgery was reported in three studies. The contamination via aerosolised blood droplets and peritoneal fluids during evacuation of the pneumoperitoneum was reported by two studies, suggesting the potential spread of HIV [35,36]. In this context, Kwak *et al.* [7] identified HBV DNA via PCR in 10 of 11 cases in surgical smoke obtained during laparoscopic surgery. Additionally, another group reported that HIV-1 can remain viable in cool aerosols generated by certain surgical power tools [6]. However, no further studies exist to determine the virus activity or comparisons between laparoscopic and open surgery. Further detailed characteristics of the included studies are summarised in Table 2. The NOS was applied to analyse the quality of data and to assess the risk of bias. Table 3 shows the NOS scores of the selected studies. The median score was 4 (interquartile range 2.5–5). In summary, different viral particles and DNA have been detected in surgical smoke and several authors suggest a higher risk when exposed, yet none have proven a direct infectious capacity.

Impact on Guidelines

A comprehensive screening of the leading societies for abdomino-pelvic surgery are summarised as follows:

The American College of Surgeons (ACS) [37] recommended considering avoiding laparoscopy. They described a higher risk of aerosolisation and droplet transmission hazard during the evacuation of pneumoperitoneum and aspiration of body fluids during laparoscopic procedures. Similarly, the European Association of Urology (EAU) Robotic Urology Section (ERUS) [38] recommend performing laparoscopic and robot-assisted surgery only if necessary, due to the possible

Table 1 Characteristics of included studies.

Reference	Country	Type of virus	Type of intervention	Study design	Conclusion
Kwak *et al.*, 2016 [7]	South Korea	HBV	Laparoscopy	Experimental	HBV was detected in surgical smoke in 10 of the 11 laparoscopic cases
Englehardt *et al.*, 2014 [35]	USA	N/A	Laparoscopy	Experimental	Contamination via aerosolised droplets of bloods during evacuation of the pneumoperitoneum
Johnson *et al.*, 1991 [6]	USA	HIV	Surgical power tools	Experimental	HIV-1 can remain viable in cool aerosols generated by certain surgical power tools
Eubanks *et al.*, 1993 [36]	USA	HIV	Laparoscopy	Experimental	Evacuation of the pneumoperitoneum during laparoscopic procedures releases aerosolised blood and peritoneal fluid with possible HIV-infection
Baggish *et al.*, 1991 [5]	USA	HIV	CO2 Laser	Experimental	Presence of proviral HIV DNA in vaporised tissue by CO_2 laser
Capizzi *et al.*, 1998 [32]	USA	N/A	CO_2 Laser	Experimental	Presence of bacteria, but no virus in laser resurfacing smoke plume
Subbarayan *et al.*, 2020 [30]	USA	HPV	Electrocautery	Experimental	No presence HPV 16 DNA in surgical smoke caused by electrocautery
Ferenczy *et al.*, 1990 [8]	USA	HPV	CO_2 Laser	Experimental	Contamination of the operator is unlikely when appropriate equipment for evacuating smoke is used
Bergbrant *et al.*, 1994 [9]	Sweden	HPV	Electrocoagulation/CO_2 Laser	Experimental	Presence of HPV DNA in nasolabial fold and nostril of personnel after surgery
Weyandt *et al.*, 2011 [29]	Germany	HPV	Multilayer argon plasma coagulation/ CO_2 Laser	Experimental	HPV DNA found in suctions filters, but not surveillance petri dishes and swabs from the glasses and nasolabial folds of surgeon
Garden *et al.*, 2002 [25]	USA	HPV	CO_2 Laser	Experimental	Collected laser plume contained bovine papillomavirus DNA in all tested laser settings (bovine papillomavirus-induced tissue)
Gloster *et al.*, 1995 [33]	USA	HPV	CO_2 Laser	Case-control	CO_2 laser surgeons have no higher risk to acquire warts than the general population
Ferenczy *et al.*, 1990 [26]	USA	HPV	CO_2 Laser	Experimental	Viral contamination of 5 cm surrounding skin after laser vaporisation
Kunachak *et al.*, 1996 [31]	Thailand	HPV	CO_2 Laser	Experimental	No viable virus in culture from laser plume and no infection in susceptible cell lines
Neumann *et al.*, 2018 [28]	Germany	HPV	Electrosurgery	Experimental	Risk of contamination with high-risk HPV from surgical plume
Zhou *et al.*, 2019 [27]	China	HPV	Electrosurgery	Experimental	Presence of HPV DNA in surgical smoke and nasal swab of surgeons
Best *et al.*, 2020 [34]	USA	HPV	Potassium titanyl phosphate laser, Coblator	Experimental	Smoke plume of treated mouse papillomavirus is capable of transmitting infection

Table 2 Further characteristics of included studies.

Reference	No. patients/ samples	Intervention	Methods	Measured outcome	Results
Kwak *et al.*, 2016 [7]	11 patients	Laparoscopic and robotic abdominal surgery	Nested PCR of obtained surgical smoke from pneumoperitoneum of hepatitis B positive patients	Detection of HBV by PCR	HBV detected in 10 of 11 cases
Englehardt *et al.*, 2014 [35]	27 patients	Laparoscopic abdominal surgery	Analysis of particulate contamination of aerosolised blood droplets resulting from pneumoperitoneum evacuation	Spatter particle size	31 to 2750 blood spatter/ analysis
Johnson *et al.*, 1991 [6]	32 samples	Oscillating bone saw, spinning router tip, electrocautery	Power tool use on known HIV-1 inoculated blood for viral culture medium, then addition of tissue cells to detect infection	Detection of HIV-1 P-24 core antigen assayed by ELISA in culture medium	Positive cell infection from oscillation bone saw (25%) and router tip (55%), but not electrocautery
Eubanks *et al.*, 1993 [36]	N/A	Laparoscopic abdominal surgery	Microscopic analysis of aerosol obtained from pneumoperitoneum evacuation	Demonstration of cells capable of carrying HIV	Identification of red blood cells, white bloods cells and cellular debris
Baggish *et al.*, 1991 [5]	12 samples	CO_2 laser vaporisation	Culture studies of vaporous debris and evacuation tube from laser vaporised HIV infected tissue culture pellets	Detection of HIV DNA by PCR	Positive in evacuation tube (33%), negative in culture medium flask
Capizzi *et al.*, 1998 [32]	13 patients	CO_2 laser resurfacing	Viral/bacterial culture of laser plume smoke	Detection of viral/ bacterial growth	No viral growth, but bacterial growth in 5 cultures
Subbarayan *et al.*, 2020 [30]	6 patients, 4 samples	Electrocautery during transoral robotic surgery/mouse tail	Surgical smoke obtained from HPV p16 induced mouse tail and patients with HPV p16-positive and -negative tumours	Detection of HPV DNA via PCR	No detectable HPV16 DNA in all samples
Ferenczy *et al.*, 1990 [8]	110 patients	CO_2 laser treatment	Swabs from patients, devices (pre-filter canister, vacuum tube), and surgeons' nasopharynx/eyelids/ears before and after laser surgery for HPV-containing genital infections	Detection of HPV DNA by PCR	Detection of HPV DNA in canister (20%), but not in tubes or on surgeons
Bergbrant *et al.*, 1994 [9]	158 samples	CO_2 laser treatment	Samples/swabs from surgeons' nostrils/nasolabial fold/ conjunctiva and surveillance petri dishes from OR before and after surgery of genital warts	Detection of HPV DNA by PCR	For nasolabial fold and nostrils, 13% and 10% positive before surgery, and 30% and 20% positive after surgery; all swabs from conjunctiva were negative
Weyandt *et al.*, 2011 [29]	106 samples	CO_2 and argon laser treatment	Samples from surveillance petri dishes, surgeons' glasses/ nasolabial folds, and suctions units during laser treatment of genital warts	Detection of HPV DNA by PCR	Detection of HPV DNA only in suction filters (30%)
Garden *et al.*, 2002 [25]	3 samples/3 calves	CO_2 laser treatment	Collection of surgical smoke from laser exposed bovine papillomavirus-induced cutaneous fibropapilloma and re-inoculation into skin of calves	Detection of viral content and tumour growth after inoculation	Detection of HPV DNA in all cases; tumour development in all cases and infected with the same type of HPV type as in laser plume
Gloster *et al.*, 1995 [33]	6124 patients 31 surgeons	CO_2 laser treatment	Comparative study between CO_2 laser surgeons and control groups (patients with warts) for samples from plantar, nasopharynx, genital/anal, face, hands	Difference in incidence, use of PPE, duration of exposure	Significant difference only in plantar, nasopharyngeal, genital/anal warts between study group and control group 2
Ferenczy *et al.*, 1990 [26]	43 patients	CO_2 laser treatment	Samples from lesion tissue, treatment field and 5 cm surrounding normal skin before and after laser surgery for HPV-containing genital infections	Detection of HPV DNA by detection kit	Detection in lesion tissue (79%), treatment field (16%) and 5 cm surrounding before (9%) and after (16%) surgery
Kunachak *et al.*, 1996 [31]	10 samples	CO_2 laser treatment	Culture growth from plume obtained from laser exposed laryngeal papilloma specimen and non-exposed laryngeal specimen; laser plume cultured with 2 cell lines (porcine and human) with Polio virus as control	Cell growth and viral infection	No cell growth or viral infection in study samples
Neumann *et al.*, 2018 [28]	24 patients	Loop electrosurgical excision procedures	Analysis of plume generated by treatment of high grade squamous intraepithelial lesion of cervix uteri	Detection of HPV DNA by EUROArray	Detection in 4 patients (16%)

Table 2 (continued)

Reference	No. patients/ samples	Intervention	Methods	Measured outcome	Results
Zhou *et al.*, 2019 [27]	134 patients, 31 surgeons	Loop electrosurgical excision procedures	Samples from cervical cells, plume, and surgeons' nasal epithelial cells before and after treatment of cervical intraepithelial neoplasia	Detection of HPV by flow fluorescence *in situ* hybridisation	Detection of HPV DNA in cervical cells (94.8%), plume (29.9%), and postoperative surgeons' nasal epithelial cells (1.5%); all preoperative nasal swab negative
Best *et al.*, 2020 [34]	39 mice	Potassium titanyl phosphate laser, Coblator	Exposure of uninfected mice with ablated tissue and surgical smoke from treatment of mice with established mouse papillomavirus tail warts	Penetrance of infection	100% penetrance at day 32 (laser) and day 52 (Coblator)

presence of viral particles, but stressed that there are no data on the presence of SARS-CoV-2 in the aerosol. They graded the priority of urological interventions in the context of the COVID-19 pandemic and suggested, e.g., the possible use of robot-assisted cystectomies in high-risk cases or severe gross haematuria. In the UK, the main surgical associations released the 'Intercollegiate General Surgery Guidance on COVID-19' [39], which clearly states that due to the possible risk of aerosol-based infection in laparoscopy only carefully selected patients should receive laparoscopic surgery, when the benefit outweighs the potential occupational risk of viral transmission. Interestingly, the guidance initially stated that due to the risk of infection via aerosol, laparoscopic surgery should not be used (25 March 2020) [40], but within a couple of days this statement was de-escalated (7 April 2020) [39].

In contrast, the joint recommendation by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the European Association for Endoscopic Surgery and other Interventional Techniques (EAES) [41] also stated that the current evidence does not support the possible higher contamination risk during MIS. They argued that proven benefits of MIS are to be considered and stress a potential for MIS ultrafiltration systems compared to open surgery. Equally, the 'Joint Statement on Minimally Invasive Gynecologic Surgery During the COVID-19 Pandemic' [42] provided detailed directives for surgical approaches for open surgery and MIS, but maintained that there is no evidence that respiratory viruses are transmitted during surgery. Taken together, there is no interdisciplinary consensus on the differing risk of transmission of SARS-CoV-2 during MIS vs open surgery. However, all societies agreed on the use of additional protective measures to minimise the risk of transmission.

On 6 April 2020, a total of 38 countries were above our cut-off of 2000 total reported COVID-19 cases per country [23]. They are listed together with recommendations of the surgical and urological society in Table 4 (list of homepage links provided in Table S1). From the 38 urological societies screened on 6 April 2020, one was excluded due to a missing homepage, seven were excluded due to lack of information in English or available translation, one was excluded due to access issues by non-members. From the remaining 29 associations, six recommended the use of risk-stratification in patient selection for surgery and two recommended considering avoiding MIS. Additionally, four societies referred to guidelines for risk stratification and surgical approach by leading international societies. The remaining associations published neither recommendations for risk stratification nor use of MIS. As for surgical societies with a focus on sub-societies for endoscopic, laparoscopic, and robotic surgery, 38 Internet presences were screened on 6 April 2020. Two were excluded due to a missing homepage and five were excluded

Table 3 NOS.

Reference	Article title	Selection	Comparability	Outcome	Total
Kwak *et al.*, 2016 [7]	Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery.	*		*	2
Englehardt *et al.*, 2014 [35]	Contamination resulting from aerosolised fluid during laparoscopic surgery.	*		*	2
Johnson *et al.*, 1991 [6]	Human immunodeficiency virus-1 (HIV-1) in the vapours of surgical power instruments.	**	*	*	4
Eubanks *et al.*, 1993 [36]	Reduction of HIV transmission during laparoscopic procedures.	*		*	2
Baggish *et al.*, 1991 [5]	Presence of human immunodeficiency virus DNA in laser smoke	**	*	*	4
Capizzi *et al.*, 1998 [32]	Microbiologic activity in laser resurfacing plume and debris.	**	*	*	4
Subbarayan *et al.*, 2020 [30]	Occupational exposure of oropharyngeal human papillomavirus amongst otolaryngologists.	**	*	*	4
Ferenczy et al., 1990 [8]	Human papillomavirus DNA in CO_2 laser-generated plume of smoke and its consequences to the surgeon.	**	**	*	5
Bergbrant *et al.*, 1994 [9]	Polymerase chain reaction for monitoring human papillomavirus contamination of medical personnel during treatment of genital warts with CO_2 laser and electrocoagulation.	**	**	*	5
Weyandt *et al.*, 2011 [29]	Low risk of contamination with human papilloma virus during treatment of condylomata acuminata with multilayer argon plasma coagulation and CO_2 laser ablation	**	**	*	5
Garden *et al.*, 2002 [25]	Viral disease transmitted by laser-generated plume (aerosol)	**	**	*	5
Gloster *et al.*, 1995 [33]	Risk of acquiring human papillomavirus from the plume produced by the carbon dioxide laser in the treatment of warts.	*	*	*	3
Ferenczy *et al.*, 1990 [26]	Carbon dioxide laser energy disperses human papillomavirus deoxyribonucleic acid onto treatment fields	**	**	*	5
Kunachak *et al.*, 1996 [31]	Are laryngeal papilloma virus-infected cells viable in the plume derived from a continuous mode carbon dioxide laser, and are they infectious? A preliminary report on one laser mode	**	**	*	5
Neumann *et al.*, 2018 [28]	Is surgical plume developing during routine LEEPs contaminated with high-risk HPV? A pilot series of experiments	*		*	2
Zhou *et al.*, 2019 [27]	Human papillomavirus DNA in surgical smoke during cervical loop electrosurgical excision procedures and its impact on the surgeon	**	**	***	7
Best *et al.*, 2020 [34]	Infectivity of murine papillomavirus in the surgical byproducts of treated tail warts	**	*	***	6

due to lack of information in English language or available translation. From the remaining 31 associations, the ACS (USA) and the Royal College of Surgeons (UK), as leading surgical societies, published both comprehensive recommendations for risk stratification and surgical approach [37,39]. The other societies referred to it or uploaded their own recommendations, leaving 15 societies without risk-stratification guidance and 17 societies without recommendation on surgical approach.

Survey of Clinical Practice

The survey was sent on 13 April 2020 and a total of 334 participants completed it. Respondents' characteristics and results are shown in Table 5 and Fig. 2. Participants mainly originated from Europe (n = 226), followed by North America (n = 53). The range of specialty included general surgery, urology, and gynaecology, with 80.8% faculty and 83.2% working in the public sector. Overall, 79% of the responders did treat patients with COVID-19 in their hospital. Only 59% of the participants were performing preoperative systematic screening for SARS-CoV-2.

Most of the respondents (98.2%) found that COVID-19 had affected their surgical programme, with 32.2% only performing urgent cases and 62.7% performing only non-elective and urgent cases. Overall, 58.5% of the surgeons postponed MIS; ~15% switched to open surgery and ~15% switched to non-surgical options.

Considering the safety protocols recommended, only 57% of the surgeons followed surgical smoke safety guidelines before the outbreak and ~75% believed that MIS remained a safe approach. Most of the participants reported the use of additional protective measures due to COVID-19, but ~25% continued working without any additional protection.

Discussion

Based on our scoping review, the current scientific evidence on intraoperative aerosol viral transmission is extremely limited. It mostly consists of experimental reports with a low level of evidence. Moreover, no study assessed specifically the risk of SARS-CoV-2 dissemination, and more importantly transmission via pneumoperitoneum. We provide the first complete scoping review on this specific topic. No article assessed the risk and protective measures needed to perform

Table 4 Overview of included urological and surgical societies and summary of uploaded national guidelines.

Country	Total cases	Urological association	Guidance patient selection	Guidance surgical approach	Surgical association	Guidance patient selection	Guidance surgical approach
USA	302 919	AUA	ACS	ACS	ACS	ACS	ACS
Spain	124 736	Asociacion Española Urología	No	No	Asociacion Española de Cirujanos	Yes	No
Italy	124 632	Società Italiana di Urologia	Yes	No	Associazione Chirurghi Ospedalieri Italiani	Yes	Yes
Germany	95 637	Deutsche Gesellschaft für Urologie	Yes	No	Deutsche Gesellschaft für Chirurgie	Yes	No
France	89 953	Association Française d'Urologie	Yes	Yes, limit MIS	Société Française de Chirurgie Oncologique	Yes	Yes, limit MIS
China	81 639	Chinese Urological Association	N/A	N/A	Chinese Society of Laparo-Endoscopic Surgery	Homepage not found	Homepage not found
Iran	55 743	Iranian Urological Association	No	No	Iranian Association of Surgeons	No	No
UK	41 903	BAUS	Member only	Member only	Royal College of Surgeons	Intercollegiate Guidance	Intercollegiate Guidance
Turkey	23 934	Turkish Association of Urology	No	No	Turkish Surgical Association	Yes	Intercollegiate Guidance
Switzerland	20 505	Schweizerische Gesellschaft für Urologie	No	No	Schweizerische Gesellschaft für Chirurgie	Refer to international guidelines	Refer to international guidelines
Belgium	18 431	Belgian Association of Urology	N/A	N/A	Royal Belgium Society of Surgery	N/A	N/A
Netherlands	16 627	Nederlandse Vereniging voor Urologie	N/A	N/A	Nederlandse Vereniging voor Chirurgische Oncologie	N/A	N/A
Canada	13 872	Canadian Urological Association	No	No	Canadian Association of General Surgeons	Yes	SAGES
Austria	11 781	Österreichische Gesellschaft für Urologie	Refer to German guidelines	ERUS	Österreichische Gesellschaft für Chirurgie	Yes	Yes, laparoscopy is safe
Portugal	10 524	Associação Portuguesa de Urologia	Yes	Yes, limit MIS	Sociedade Portuguesa de Cirurgia	No	Yes, limit MIS
South Korea	10 156	The Korean Urological Association	No	No	The Korean Society of Endoscopic and Laparoscopic	No	No
Brazil	9391	Sociedade Brasileira de Urologia	No	No	Colégio Brasileiro de Cirurgiões	No	No
Israel	7851	Israel Association of Urology	N/A	N/A	Israel Surgical Association	N/A	N/A
Sweden	6443	Svensk Urologisk Förening	No	No	Svensk Kirurgisk Förening	Intercollegiate Guidance	Intercollegiate Guidance
Norway	555	Norsk Urologisk Foerening	No	No	Norsk Kirurgisk Foerening	No	No
Australia	555	Urological Society of Australia and New Zealand	Yes	SAGES	Royal Australian College of Surgeons	Yes	SAGES
Russia	4731	Russian Society of Urology	No	No	Russian Society of Surgeons	No	No
Ireland	4604	Irish Society of Urology	No	No	Royal College of Surgeons in Ireland	Intercollegiate Guidance	Intercollegiate Guidance
Czechia	4362	Ceska Urologicka Spokecnost	N/A	N/A	Czech Society for Surgery	N/A	N/A
Chile	4161	Sociedad Chilena de Urología	No	No	Sociedad de Cirujanos de Chile	No	No
Denmark	4077	Dansk Urologisk Selskab	No	No	Dansk Kirurgisk Selskab	Yes	No
Poland	3627	Polskie Towarzystwo Urologiczne	N/A	N/A	Towarzystwo Chirurgów Polskich	N/A	N/A
Romania	3613	Romanian Association of Urology	No	No	Asociaţia Româna pentru Chirurgie Endoscopică	No	No
Malaysia	3483	Malaysian Urological Association	No	No	College of Surgeons of Malaysia	Yes	Yes, limit MIS
Ecuador	3465	Sociedad Ecuatoriana de Urología	No	No	Sociedad de Ecuatoriana de Cirugía	No	No
Philippines	3094	Phillippine Urological Association	No	No	Phillipine Society of General Surgeons	No	No

Table 4 (continued)

Country	Total cases	Urological association	Guidance patient selection	Guidance surgical approach	Surgical association	Guidance patient selection	Guidance surgical approach
India	3082	The Urological Society of India	Yes	No	Association of Surgeons in India	No	No
Japan	2935	Japanese Urological Association	ACS	ACS	Japanese Surgical Society	ACS	ACS
Pakistan	2818	Pakistan Association of Urological Surgeons	No	No	Society of Surgeons of Pakistan	No	No
Luxembourg	2729	Societe Luxembourgeoise D'Urologie	No homepage found	No homepage found	Societe Luxembourgeoise de Chirurgie	Homepage not found	Homepage not found
Saudi Arabia	2179	Saudi Urologic Association	No	No	Saudi Surgical Society	No	No
Indonesia	2092	Indonesian Urological Association	No	No	Indonesian College of Surgeons	No	No
Thailand	2067	Thai Urological Association	N/A	N/A	The Royal College of Surgeons Thailand	No	No

Table 5 Characteristics of survey respondents (n = 334).

Variable	*N* (%)
Continent of residence	
Africa	10 (3)
Asia	39 (12)
Europa	226 (68)
North America	53 (16)
South America	6 (2)
Specialty	
Gynaecology	11 (3)
Surgery	29 (9)
Urology	294 (88)
Position	
Faculty	270 (81)
Resident	64 (19)
Hospital	
Private	56 (17)
Public	278 (83)
Treating patients with COVID-19 in hospital	
No	73 (22)
Yes	261 (78)
Systematic screening for COVID-19 before surgery	
No	137 (41)
Yes	197 (59)

MIS during COVID-19, including the assessment of both the contemporary guidelines and real-life practice [3,43–46]. The reason for the limited knowledge probably lies with the difficulty of performing studies on the topic and to obtain high-quality data. As a comparison, despite the AIDS epidemic in the early 1980s and nowadays >40 million infected people [47], only a few publications on intraoperative transmission risk of HIV exist. This suggests that it is likely that it will be difficult to assess the potential risk of SARS-CoV-2 transmission. Currently, one prospective case–control study to investigate the presence and infectiousness of SARS-CoV-2 in aerosols from laparoscopic or open abdominal surgery is estimated to start in August 2020 (NCT04444687). A separate consideration of studies for transmission of SARS-CoV-2 and other viruses is provided in the supplementary material (Table S2).

A guideline's objective is to assist medical professionals in clinical decision-making and management of patients based on the best scientific evidence available. Thus, it must have been challenging to form any recommendations based on the limited knowledge available, as outlined above. The few recommendations in guidelines are, therefore, to be considered as based on expert consensus and the precaution principle. In our critical opinion, they were given too hastily when it comes to the risks associated with MIS. Especially in challenging times, such as these, caution should prevail to not deviate from standards, unless the burden of proof is fulfilled. Indeed, despite the most widely accepted guidelines cautioning against MIS, only 25% of surgeons abided by that recommendation. We believe that this reluctance to comply with the recommendations is understandable. More research

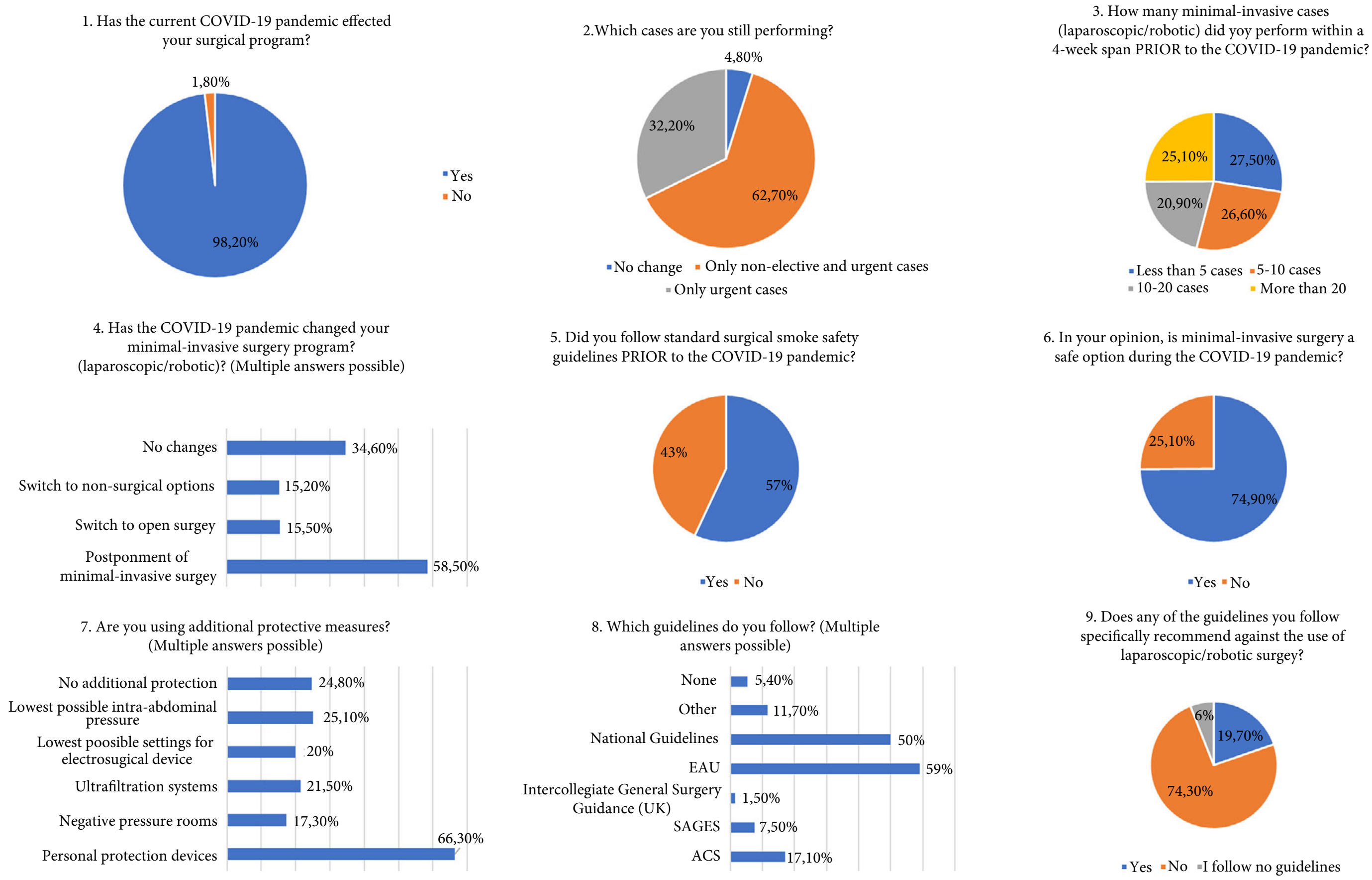


Fig. 2 Summary of survey results (questions 1–9).

is needed to evaluate this question conclusively. Until then current standards should be maintained, as any deviation could harm the patient based on substandard evidence.

The results of our present survey emphasise the immense impact of COVID-19 on surgical activity worldwide and the discrepancies between implemented guidelines and the real-life practice. Recent publications declared MIS during COVID-19 a safe option with no evidence to support an increased risk to operating room personnel with adequate protective measures [45,48,49]. Most of the respondents (~75%) agree with this opinion; interestingly, ~60% delayed MIS and 15% switched to open surgery or non-surgical options. Furthermore, it also confirms that the proposed safety measures are not being conclusively followed. Only 3.5% of the responders were following all the different protective measures recommended among the different guidelines, although almost all responders stated that they follow at least one national or international guideline. Given the worldwide shortage of medical equipment [50] and the different geographical impact [23], it is understandable that the proposed safety measures cannot be implemented in the same manner across different settings/geographies. Finally, different surveys on surgical activity and surgical approach exist, but our present survey is the first one to consider the specific impact of the risk of transmission during MIS.

The results of the present report should be considered in the context of several limitations. To date, there is no proven intraoperative aerosol transmission risk due to pneumoperitoneum. However, this is based on a meagre availability of data. Consequently, the validity of our present scoping review is limited by the scarcity of publications, the low level of evidence, and the lack of recently published data. Hence, published guidelines are also limited in their validity and our present findings mirror the lack of consensus on this topic. Additionally, the findings on HPV, HIV, and HBV do not offer direct evidence for SARS-CoV-2. Furthermore, the data quality analysis of the selected studies, based on the NOS, indicated limited reliability and validity, with mostly weak evidence and non-representative sample sizes.

One natural limitation of survey research is the reliance on the self-reflection of the respondents. Also, the survey was kept short in the knowledge of the workload of physicians. To capture a more precise picture, key informant interviews with leading experts could additionally improve the reliability of the results.

In conclusion, there is no convincing evidence to support the concerns of an intraoperative viral transmission via pneumoperitoneum aerosolisation. However, the present study indicated that this unparalleled health crisis led to the application of the 'better safe than sorry' principle, thereby deviating from the scientific methodology used to create high-quality guidelines. Usually guideline development involves a multi-step development process with standard requirements and evaluation of the level of evidence. Interestingly, real-life experience reported by our present survey shows a lack of compliance to the ad hoc COVID-19 guideline recommendations on MIS developed during the pandemic, most probably because of the low level of evidence.

Risk of intraoperative aerosol transmission of SARS-CoV-2 through pneumoperitoneum has been putting pressure on the different surgical societies to make recommendations based on limited information in accordance with the precaution principle. Nevertheless, these recommendations are not supported by the actual literature and they do not seem to be followed by most surgeons. Future studies on potential transmission risk during MIS should be performed. Expert consensus proposed during the crisis, without evidence and proper rigorous methodology should be limited and interpreted with caution.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

None of the authors have conflicts of interest to disclose.

References

1 **Holshue ML, DeBolt C, Lindquist S et al.** First case of 2019 novel coronavirus in the United States. *N Engl J Med* 2020; 382: 929–36

2 **Xiao F, Tang M, Zheng X, Liu Y, Li X, Shan H.** Evidence for gastrointestinal infection of SARS-CoV-2. *Gastroenterology* 2020; 158: 1831–1833.e3

3 **Zheng MH, Boni L, Fingerhut A.** Minimally invasive surgery and the novel coronavirus outbreak: lessons learned in China and Italy. *Ann Surg* 2020; 272: e5–6.

4 **Li CI, Pai JY, Chen CH.** Characterization of smoke generated during the use of surgical knife in laparotomy surgeries. *J Air Waste Manag Assoc* 2020; 70: 324–32

5 **Baggish MS, Polesz BJ, Joret D, Williamson P, Refai A.** Presence of human immunodeficiency virus DNA in laser smoke. *Lasers Surg Med* 1991; 11: 197–203

6 **Johnson GK, Robinson WS.** Human immunodeficiency virus-1 (HIV-1) in the vapors of surgical power instruments. *J Med Virol* 1991; 33: 47–50

7 **Kwak HD, Kim SH, Seo YS, Song KJ.** Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. *Occup Environ Med* 2016; 73: 857–63

8 **Ferenczy A, Bergeron C, Richart RM.** Human papillomavirus DNA in CO2 laser-generated plume of smoke and its consequences to the surgeon. *Obstet Gynecol* 1990; 75: 114–8

9 **Bergbrant IM, Samuelsson L, Olofsson S, Jonassen F, Ricksten A.** Polymerase chain reaction for monitoring human papillomavirus contamination of medical personnel during treatment of genital warts with CO2 laser and electrocoagulation. *Acta Derm Venereol* 1994; 74: 393–5

10 **Barrett WL, Garber SM.** Surgical smoke: a review of the literature. Is this just a lot of hot air? *Surg Endosc* 2003; 17: 979–87

11 **Alp E, Bijl D, Bleichrodt RP, Hansson B, Voss A.** Surgical smoke and infection control. *J Hosp Infect* 2006; 62: 1–5

12 **Mowbray N, Ansell J, Warren N, Wall P, Torkington J.** Is surgical smoke harmful to theater staff? A systematic review. *Surg Endosc* 2013; 27: 3100–7

13 **Fencl JL.** Guideline implementation: surgical smoke safety. *AORN J* 2017; 105: 488–97

14 **Ball K.** Compliance with surgical smoke evacuation guidelines: implications for practice. *AORN J* 2010; 92: 142–9

15 **Wang J, Du G.** COVID-19 may transmit through aerosol. *Ir J Med Sci* 2020 [Epub ahead of print]. DOI: 10.1007/s11845-020-02218-2

16 **Yu ITS, Li Y, Wong TW et al.** Evidence of airborne transmission of the severe acute respiratory syndrome virus. *N Engl J Med* 2004; 350: 1731–9

17 **Adhikari U, Chabrelie A, Weir M et al.** A case study evaluating the risk of infection from Middle Eastern Respiratory Syndrome Coronavirus (MERS-CoV) in a Hospital Setting Through Bioaerosols. *Risk Anal* 2019; 39: 2608–24

18 **Zhang H, Li X, Ma R et al.** Airborne spread and infection of a novel swine-origin influenza A (H1N1) virus. *Virol J* 2013; 10: 204

19 **Kulkarni H, Smith CM, Lee DD, Hirst RA, Easton AJ, O'Callaghan C.** Evidence of respiratory syncytial virus spread by aerosol time to revisit infection control strategies? *Am J Respir Crit Care Med* 2016; 194: 308–16

20 **Stahel PF.** How to risk-stratify elective surgery during the COVID-19 pandemic? *Patient Saf Surg* 2020; 14: 8

21 **Liberati A, Altman DG, Tetzlaff J et al.** The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med* 2009; 6: e1000100

22 **Ottawa Hospital Research Institute** [Internet]. Available at: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed August 2020

23 **Worldometer.** Coronavirus Cases [Internet]. Worldometer. 2020; pp. 1–22. Available at: https://www.worldometers.info/coronavirus/coronavirus-cases/#daily-cases. Accessed April 2020

24 **Eysenbach G.** Improving the quality of web surveys: The Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res* 2004; 6: e34

25 **Garden JM, Kerry O'Banion M, Bakus AD, Olson C.** Viral disease transmitted by laser-generated plume (aerosol). *Arch Dermatol* 2002; 138: 1303–7

26 **Ferenczy A, Bergeron C, Richart RM.** Carbon dioxide laser energy disperses human papillomavirus deoxyribonucleic acid onto treatment fields. *Am J Obstet Gynecol* 1990; 163: 1271–4

27 **Zhou Q, Hu X, Zhou J, Zhao M, Zhu X, Zhu X.** Human papillomavirus DNA in surgical smoke during cervical loop electrosurgical excision procedures and its impact on the surgeon. *Cancer Manag Res* 2019; 11: 3643–54

28 **Neumann K, Cavalar M, Rody A, Friemert L, Beyer DA.** Is surgical plume developing during routine LEEPs contaminated with high-risk HPV? A pilot series of experiments. *Arch Gynecol Obstet* 2018; 297: 421–4

29 **Weyandt GH, Tollmann F, Kristen P, Weissbrich B.** Low risk of contamination with human papilloma virus during treatment of

condylomata acuminata with multilayer argon plasma coagulation and CO_2 laser ablation. *Arch Dermatol Res* 2011; 303: 141–4
30 **Subbarayan RS, Shew M, Enders J, Bur AM, Thomas SM.** Occupational exposure of oropharyngeal human papillomavirus amongst otolaryngologists. *Laryngoscope* 2020; 130: 2366–71.
31 **Kunachak S, Sithisarn P, Kulapaditharom B.** Are laryngeal papilloma virus-infected cells viable in the plume derived from a continuous mode carbon dioxide laser, and are they infectious? A preliminary report on one laser mode. *J Laryngol Otol* 1996; 110: 1031–3
32 **Capizzi PJ, Clay RP, Battey MJ.** Microbiologic activity in laser resurfacing plume and debris. *Lasers Surg Med* 1998; 23: 172–4
33 **Gloster HM, Roenigk RK.** Risk of acquiring human papillomavirus from the plume produced by the carbon dioxide laser in the treatment of warts. *J Am Acad Dermatol* 1995; 32: 436–41
34 **Best SR, Esquivel D, Mellinger-Pilgrim R, Roden RB, Pitman MJ.** Infectivity of murine papillomavirus in the surgical byproducts of treated tail warts. *Laryngoscope* 2020; 130: 712–7
35 **Englehardt RK, Nowak BM, Seger MV, Duperier FD.** Contamination resulting from aerosolized fluid during laparoscopic surgery. *JSLS* 2014; 18: e2014.00361
36 **Eubanks S, Newman L, Lucas G.** Reduction of HIV transmission during laparoscopic procedures. *Surg Laparosc Endosc* 1993; 3: 2–5
37 COVID-19: Considerations for Optimum Surgeon Protection Before, During, and After Operation [Internet]. Available at: https://www.facs.org/covid-19/clinical-guidance/surgeon-protection. Accessed April 2020
38 EAU Robotic Urology Section (ERUS) guidelines during COVID-19 emergency | Uroweb [Internet]. Available at: https://uroweb.org/eau-robotic-urology-section-erus-guidelines-during-covid-19-emergency/. Accessed April 2020
39 Intercollegiate General Surgery Guidance on COVID-19 UPDATE | RCSEd [Internet]. Available at: https://www.rcsed.ac.uk/news-public-affairs/news/2020/march/intercollegiate-general-surgery-guidance-on-covid-19-update. Accessed April 2020
40 Urgent Intercollegiate General Surgery Guidance on COVID-19 | ACPGBI [Internet]. Available at: https://www.acpgbi.org.uk/news/urgent-intercollegiate-general-surgery-guidance-on-covid-19/. Accessed April 2020
41 SAGES and EAES Recommendations Regarding Surgical Response to COVID-19 Crisis - SAGES [Internet]. Available at: https://www.sages.org/recommendations-surgical-response-covid-19/. Accessed April 2020
42 COVID-19: Joint Statement on Minimally Invasive Gynecologic Surgery - AAGL » AAGL [Internet]. Available at: https://www.aagl.org/news/covid-19-joint-statement-on-minimally-invasive-gynecologic-surgery/. Accessed April 2020
43 **Steward J, Kitley WR, Schmidt CM, Sundaram CP.** Urologic surgery and COVID-19: How the pandemic is changing the way we operate. *J Endourol* 2020; 34: 541–9
44 **De Simone B, Chouillard E, Di Saverio S et al.** Emergency surgery during the COVID-19 pandemic: what you need to know for practice. *Ann R Coll Surg Engl* 2020; 102: 323–32
45 **Vigneswaran Y, Prachand VN, Posner MC, Matthews JB, Hussain M.** What is the appropriate use of laparoscopy over open procedures in the current COVID-19 climate? *J Gastrointest Surg* 2020; 24: 1686–91
46 **Veziant J, Bourdel N, Slim K.** Risks of viral contamination in healthcare professionals during laparoscopy in the Covid-19 pandemic. *J Visc Surg* 2020; 157: S59–62.
47 AIDS statistics – Worldometer [Internet]. Available at: https://www.worldometers.info/aids/. Accessed May 2020
48 **Francis N, Dort J, Cho E et al.** SAGES and EAES recommendations for minimally invasive surgery during COVID-19 pandemic. *Surg Endosc* 2020; 34: 2327–31
49 **Morris SN, Fader AN, Milad MP, Dionisi HJ.** Understanding the “Scope” of the problem: why laparoscopy is considered safe during the COVID-19 pandemic. *J Minim Invas Gynecol* 2020; 27: 789–91
50 **Ranney ML, Griffeth V, Jha AK.** Critical supply shortages – the need for ventilators and personal protective equipment during the Covid-19 pandemic. *N Engl J Med* 2020; 382: e41

Correspondence: Mesut Remzi, Department of Urology, Medical University of Vienna, Währinger Gürtel 18-20, 1090 Vienna, Austria.

e-mail: mesut.remzi@meduniwien.ac.at

Abbreviations: ACS, American College of Surgeons; CHERRIES, Checklist for Reporting Results of Internet E-Surveys Checklist for Reporting Results of Internet E-Surveys; COVID-19, coronavirus disease 2019; EAES, European Association for Endoscopic Surgery and other Interventional Techniques; ERUS, European Association of Urology Robotic Urology Section; HBV, hepatitis B virus; HPV, human papilloma virus; MIS, minimally invasive surgery; NOS, Newcastle–Ottawa Scale; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses; SAGES, Society of American Gastrointestinal and Endoscopic Surgeons; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Search strategy.
Appendix S2. Survey.
Appendix S3. PRISMA 2009 checklist.
Table S1. Surgical and urological society homepage links.
Table S2. Transmission of SARS-CoV-2 and other viruses.