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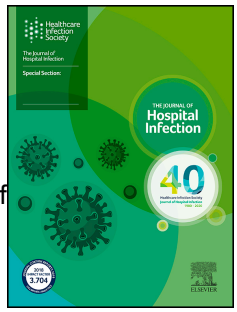

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Title Page

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What is the evidence that medical procedures which induce coughing or involve respiratory suctioning are associated with increased generation of aerosols and risk of SARS-CoV-2 infection? A rapid systematic review

Summary

The risk of transmission of SARS-CoV-2 from aerosols generated by medical procedures is a cause for concern. This rapid systematic review aimed to evaluate the evidence for aerosol production and transmission of respiratory infection associated with procedures that involve airway suctioning or induce coughing/sneezing.

The review was informed by PRISMA guidelines. Searches were conducted in PubMed for studies published between 1/1/2003 and 6/10/2020. Included studies examined whether nasogastric tube insertion, lung-function tests, nasoendoscopy, dysphagia assessment or suctioning for airway clearance result in aerosol generation or transmission of SARS-CoV-2, SARS-CoV, MERS, or influenza. Risk of bias assessment assessed robustness of measurement, control for confounding and applicability to clinical practice.

Eighteen primary studies and two systematic reviews were included. Three epidemiological studies found no association between nasogastric tube insertion and acquisition of respiratory infections. One simulation study found low/very low production of aerosols associated with pulmonary lung function tests. Seven simulation studies of endoscopic sinus surgery suggested significant increases in aerosols but findings were inconsistent, two clinical studies found airborne particles associated with the use of microdebriders/drills. Some simulation studies did not use robust measures to detect particles and are difficult to equate to clinical conditions.

There was an absence of evidence to suggest that the procedures included in the review were associated with an increased risk of transmission of respiratory infection. In order to better target precautions to mitigate risk, more research is required to determine the characteristics of medical procedures and patients that increase the risk of transmission of SARS-CoV-2.

Key words: aerosol generating procedure, respiratory infection, SARS-CoV-2, rapid systematic review, aerobiology, epidemiology, cough, suction, nasoendoscopy, nasogastric tube, lung function test

Background

Available evidence suggests that SARS-CoV-2 is emitted from an infected person's mouth or nose in small liquid particles as they breathe, speak, cough or sneeze. Particles range in size from larger respiratory 'droplets' (>10 um) to smaller 'aerosols' (<10 um) and fine particles (<1 um). Transmission mainly occurs during close contact when the virus is inhaled or inoculated onto the mouth, nose or eyes of a susceptible person and depends on the amount of viable virus present and the infection control measures that are in place.[1] Current World Health Organisation (WHO) and United Kingdom (UK) advice is that contact and droplet precautions, with the use of fluid-resistant surgical masks for close contact, are recommended for care of patients with SAR-CoV-2 infection. Airborne precautions (including the use of N95, FFP2 or FFP3 respirators) are recommended when aerosol generating procedures (AGPs) are being performed. Although not supported by evidence, the WHO recognises that some healthcare workers may place high value on the potential benefits of respirators and wish to use them in settings without AGPs.[1,2]

Historically, respiratory particles have been categorised as droplets which are deposited rapidly because of their mass and aerosols which are smaller and travel over longer distances.[3,4] However, it is now recognised that there is a continuum of particle sizes and aerosols which can be generated by breathing, speaking and coughing and can be present at both short and long distances.[5] The risk that aerosols are able to transmit infection is influenced by a range of other factors including the amount of virus in the particle, the speed and turbulence of emission, and properties of the ambient environment.[6] Although particles < 10 um can remain airborne for longer than larger respiratory droplets (>10 um), in typical particle size distributions a relatively small portion of total volume are in this range. Establishing the risk of transmission of SARS-CoV-2 associated with respiratory aerosols therefore requires evidence derived from different study designs. Laboratory-based studies can only provide evidence for part of the transmission process and demonstrate potential

rather than actual routes of transmission, while clinical studies can provide evidence of actual transmission although are more difficult to conduct and interpret.

Some medical or patient care procedures are thought to increase the generation of respiratory aerosols. Following the SARS epidemic in 2003, the WHO defined 'high-risk AGP' as medical procedures that 'have been reported to be aerosol-generating and consistently associated with an increased risk of pathogen transmission' and recommended the application of enhanced precautions for staff performing them.[8] The SARS-CoV-2 pandemic has raised concerns about a range of other medical procedures that have the potential to generate respiratory aerosols either as a result of the procedure or because of its propensity to induce coughing or sneezing in the patient.

We undertook this review to evaluate whether medical procedures which induce coughing/sneezing or involve respiratory airway suctioning, generate infectious aerosols and are associated with a risk of transmission of respiratory infection, including SARS-CoV-2. The procedures under consideration have not been previously defined as high-risk aerosol generating procedure (HR-AGP) but have been highlighted by clinicians as procedures of concern.[9] This review sought to evaluate evidence to determine if these procedures generate infectious aerosols and are associated with a risk of transmission of respiratory infection in order to inform guidance for healthcare professionals caring for patients with SARS-CoV-2. Two main questions were addressed:

1. Does evidence suggest that medical procedures which induce coughing/sneezing or involve respiratory airway suctioning result in infectious aerosol production?
2. And if yes, what is the associated risk of transmission of SARS-CoV-2?

Methods

As the assessment of evidence was required urgently to underpin guidance for use by healthcare professionals we adopted a rapid review approach, meaning that there was some deviation from standard systematic review procedures.[10] For example, although we produced a protocol, we were not able register it on Prospero as data extraction began before the protocol was finalised (Prospero requires registration before data extraction

commences); the protocol has been published elsewhere for transparency.[11] This rapid systematic review was informed by PRISMA guidelines. However, it should be noted that specific rapid review guidelines are not currently available.[12] Therefore, to ensure transparency we provide a full account of the review procedures below.

Search strategy

Searches were conducted by an information specialist (CS) in PubMed for studies published between 1st January 2003 and 6th October 2020. The search terms are detailed in web-appendix 1 and included terms reflecting aerosol generation and transmission from droplets and /or aerosols, respiratory secretions, coughing, sputum, and aerosols plus the set of procedures of interest (Table 1). In addition, the references of included articles were examined to identify any additional studies.

Inclusion/ exclusion criteria

The population of interest was adults and children with or without clinically suspected or confirmed COVID-19 or other respiratory infection (SARS, MERS, and influenza) or a simulated exposure model (e.g. using human volunteers, cadavers etc). The exposure of interest was one or more of the 'procedures of concern' shown in Table 1. The outcome of interest was the number and size of respiratory particles generated during the procedure and/or rate of infection with respiratory pathogens among exposed staff.

Study designs eligible for inclusion were case reports, case series, case control, outbreak studies, intervention studies (all designs) and systematic reviews reporting a search strategy involving multiple databases and explicit inclusion criteria. Studies were included if published in English from 2003. Only studies that reported original data were included, correspondence or comment pieces, in vitro and vaccine studies and predictive modelling studies were excluded.

The underlying evidence is heterogeneous, including different types of studies, both surgical and epidemiological, some with limited numbers of studies and others without potentially confounding factors. However, because of the limited amount of evidence, the full range of study types has been considered.

Study selection

Search results were screened using EPPI-Reviewer software.[13] One reviewer (JT) screened all titles and abstracts assisted by machine learning to prioritise potentially relevant papers. A second reviewer then independently screened the titles and abstracts provisionally included by JT and the excluded titles and abstracts that machine learning identified as most likely to have been erroneously excluded. Disagreements were resolved by discussion. Two reviewers (GC, JW) then independently screened the full reports of included references (n=68) and there was no disagreement. Reference checking of papers flagged by the full-text screeners as potential sources of further evidence was undertaken by KS.

Risk of bias, data extraction and synthesis

In line with best practice, available time and consistency requirements of a rapid review, one reviewer (KS) extracted all the data and a sample of 20% of papers were checked by a second reviewer (AO).[10,14] An independent panel reviewed all the papers and evidence tables to check the accuracy of the data and interpretation of the evidence.

Risk of bias

Since high quality evidence was unlikely to be available, evidence would be drawn from both experimental laboratory-based studies (such as cadaveric simulation studies) and observational studies of clinical practice. Therefore, in line with recommendations for rapid reviews the quality assessment for each study was focused on factors most important for decision-making.[10] AO, KS, JT and AS developed a bespoke risk of bias tool to assess each study according to a) the robustness of measurement, b) control for confounding and c) applicability to clinical practice. These dimensions are illustrated in Figure 1 below. Details of the assessment for each study are provided in the Evidence Tables (Tables 2 - 6) in the column 'Study contribution/limitations'.

Data extraction and synthesis

A standardised data extraction form was developed in order to produce a summary of each study. These summaries were then collated in evidence tables for each of the procedures of interest (nasogastric tube insertion, pulmonary lung function testing, suctioning for airway clearance, dysphagia assessment and nasoendoscopic procedures). Data were extracted on the following dimensions:

- *Study details:* Country, aim, design.
- *Procedures and measures:* procedures performed (on, by, where, number of repetitions) outcome measure type (e.g. virus transmission, aerosol size, spread, density) and method (e.g. virus transmission confirmed by antibody test, or aerosols captured by photodocumentation, particle sizer).
- *Findings:* Key conclusions and detailed findings e.g. relative risk of virus transmission with 95% confidence intervals, mean change in particle concentration etc.
- *Risk of bias assessment:* as described above.

The synthesis of study findings was organised according to each of the procedures of interest. Findings were narratively synthesised to examine if consistent patterns in the direction of effect could be identified. An overview of findings from systematic reviews involved examining the extent of relevant evidence and authors conclusions.

Findings

A total of 913 documents were identified in the search of which six were duplicates. A further three papers were identified from reference-checking and a further rapid systematic review published after the search was conducted. Following application of the inclusion criteria, 20 relevant papers were identified; 18 primary studies and two systematic reviews Figure 2).

Overview of primary studies

Nine of the 18 studies provided evidence on endoscopic sinus surgery[15-23], six studies focused on suctioning for airway clearance[23-28], four outpatient endoscopy[22,23,30,31], two nasogastric tube insertion[26,27] and one lung function testing[32]. None of the primary studies focused on procedures or testing for dysphagia. Most studies focused exclusively on one or

more of the six procedures of interest; the remainder included evidence on a wider range of procedures. For this review we only extracted data on the procedures of interest.

All studies aimed to determine whether procedures put healthcare workers (HCW) at risk, either by examining whether procedures generate aerosols or droplets[15-25,28-32] or whether procedures are associated with infection risk.[25,26,27] Some studies also evaluated whether one or more patient actions generated aerosols or droplets. Patient actions measured included coughing[22,24,29,30,32], sneezing[22,23,30], speech[22,30], heavy breathing[22], swallowing[30], tongue protrusion[30] and vomiting.[29] Finally, several studies evaluated whether a range of devices are effective in reducing the spread of aerosols or droplets during procedures. Devices included masks[23,24,25,29], drapes[15], smoke evacuation system[19] and suctioning.[19,20,21]

Fewer than half of the primary studies were clinically-based involving actual patients[15,18,25-28,31]; the remainder were simulations of procedures under experimental conditions and involved volunteers[30,32,22]; cadavers[17,19,20,21,22,23] ; human patient simulators[24,29] or porcine tissue[16].

Measurement of outcomes

Of three studies measuring transmission, one employed a measure of the presence or viral genome (PCR test), one a test for antibodies, and one antibody tests or case definitions. Of the 15 studies measuring aerosols / droplets almost half used an optical particle counter or sizer to capture data[18,19,21,22,28,31,32]. The remainder used a method to enhance visualisation of aerosols or droplets so that they could be captured using video or camera technology, including fluorescein dye[15,17,20 ,23,29], smoke[17,24] or green laser[30]. One study used both smoke and fluorescein dye[17].

Findings on nasogastric tube insertion (2 studies)

Both studies employed a retrospective cohort design and examined the association between performing nasogastric tube insertion and SARS infection among HCW in Canada (Table 2). One study[26] found that there was no evidence of an association between nasogastric tube insertion and SARS infection based on data from 32 nurses who were involved in the treatment of three infected patients of whom eight acquired SARS. Of 23 nurses who

undertook high risk procedures and consistently wore N95 or fluid resistant surgical masks (FRSM), three (13%) acquired SARS compared with five of the nine nurses who did not consistently wear a mask (56%) (RR 0.23; 95% CI 0.07 to 0.78, p = 0.02). Only three procedures were associated with a significant risk of SARS acquisition - intubation and suctioning prior to intubation (RR 4.2; 95%CI 1.58 – 11.4; p = 0.04) and manipulation of oxygen mask (RR 9.0; 95%CI 1.25 – 64.9; p<0.01). The second study[27] of 625 healthcare workers who provided care to 45 patients with SARS who underwent intubation also found no evidence of an association between nasogastric tube insertion and SARS infection. This was based on a multivariate analysis of a range of clinical procedures performed by 624 HCW who cared for 45 patients with SARS. Most staff wore FRSM (82%), only 4% wore N95 and 8% wore no mask. Twenty-six healthcare workers acquired SARS and the factors that were significantly associated with SARS acquisition were being a paramedic, having less infection control training, wearing less personal protective equipment and participation in administering non-invasive, fibreoptic or manual ventilation.

The evidence from these studies relates to patients with SARS and there may therefore be differences in terms of risk of transmission to SARS-CoV-2. In one study[26] the exposure to three patients with SARS occurred during a period of 6 to 14 days between admission and death, which reflects the period of peak viral load associated with SARS.[35] The second study was focused on high-risk exposure to healthcare workers who provided care to SARS patients in the period 24 hours before to 4 hours after intubation. Intubation is likely to present similar risks in patients with SARS-CoV-2.[27] Whilst these studies contribute evidence about infection risk in real-world clinical practice, there are several limitations. Firstly, the studies do not provide evidence about whether the procedures generate airborne particles. Secondly, the studies used case records and participant recall; whilst case records may be robust it remains unclear which type of data are used to substantiate tube insertion and where the evidence relies on recall it may be at risk of recall bias. Thirdly, the design used in both studies is at high risk of confounding; in each study HCWs performed multiple procedures (not just nasogastric tube insertion) and it is unclear which (if any) are responsible for the infection and it cannot be ruled out that HCWs may have acquired the infection from another source including the community.

Findings on pulmonary lung-function testing (n=1 study)

A study by Greening *et al* used a simulation design involving healthy volunteers to examine aerosol / droplet production following pulmonary lung-function tests (tidal breathing, forced expiratory volume, slow vital capacity (SVC) following inspiration from functional residual capacity, and SVC following inspiration from residual capacity) and association with coughing (see Table 3).[32] The study found very low particle emission in tidal volume and SVC from functional residual capacity, and low emission during forced expiratory volume. Coughing resulted in the highest mass of exhaled particles compared with all other manoeuvres, with a 640% (95%CI 230-1570, P < .01) increase compared with SVC following inspiration from functional residual capacity.[32]

Whilst the study provides evidence about aerosol / droplet generation from pulmonary lung-function tests there are several limitations. Firstly, the study used 'healthy volunteers' and it is unclear how aerosol production might be affected in those with lung conditions or with a viral infection. Secondly, in-line filters, which would be routinely used in lung function laboratories, were not used during these tests and these would effectively filter airborne particles. Thirdly, it is unclear how appropriate the Particles in Exhaled Air particle sizer / counter system used in this study was for measuring aerosols / droplets in patients with a virus; the authors note that it registers mostly small droplets from the small airways, and virus are likely to be present in droplets from both upper and lower respiratory tract.

Findings on endoscopic sinus surgery (n=9 studies)

Two studies were observations of clinical practice, examining aerosol / droplet generation among patients whose SARS-Cov-2 infection status is unknown[15] or patients who have received a negative test result.[18] Of the remaining seven studies, most were cadaveric simulations[17,19,20,21,22,23], and one used porcine tissue[16] (see Table 4). The findings from these studies were not consistent.

Of the two clinical observations, one[18] found that non-powered instrumentation was not associated with a significant increase in concentration of airborne particles compared with the pre-instrumentation level (mean change = 0.0253 particles/cm^3 p = 0.34) but the increase was significant for drilling and microdebrider use (mean change 0.0853

particles/cm^3, p=0.001; 0.0644 particles/cm^3, p=0.001). 70.3% of all particles measured were at the smallest reported size of detection (0.3µm). The second clinical observation[15] found minimal contamination beyond the immediate surgical field.

All seven simulation studies evaluated drilling, of which six reported that it resulted in significant increase in aerosol generation[16,17,19-23] and one reported that it did not[20]. In contrast to Murr et al[18], microdebriders evaluated in five simulation studies all reported no aerosol / droplet generation[17,19,20,22,23] . Of five studies evaluating non-powered instruments, one reported significant aerosol / droplet generation compared with baseline (mean change 1.29 particles/cm^3, p=0.001) and increase in smaller particles (0.30-0.37µm)[19]. The other four reported no aerosol / droplet generation[16,20,22,23] . Of three simulation studies evaluating electrocautery, all concluded that it resulted in a significant increase in aerosol / droplet generation[16,19,22] . Three simulation studies examined external activation of powered instruments[17,20,23] with all three reporting some increase in generation of aerosols or droplets. Nasal suctioning did not generate significant airborne aerosols in range 1-10µm[22] and using suction mitigated the increase in aerosols generated by drilling[19,20,21] and a negative pressure masks technique was reported to eliminate large droplets and reduce small aerosol particle concentration by 98%[17].

None of the studies provide evidence in relation to patients with COVID-19 or other respiratory infections and each of the studies has some limitations. One clinical observation study[18] appears to use robust measures and account for potential confounders, but the study by David *et al* 2020[15] does not. The cadaveric and porcine simulation studies do not account for patient factors such as breathing coughing, nasal secretions, etc and whilst some of these simulations appear to use robust measures and account for potential confounders many do not (see Table 4).

Findings on outpatient nasendoscopyendoscopy (n=4 studies)

One study conducted in the USA used a clinical observation design and examined aerosol / droplet generation among patients who have received a negative SARS-Cov-2 test result. The remaining three studies were simulations (one cadaveric and two healthy volunteers). The findings from these studies were not consistent. One clinical observation[31] found that

diagnostic nasal endoscopy with a rigid endoscope was not associated with increased particle aerosolization, but that sinonasal debridement, endonasal non-powered and suction instrumentation were associated with increased particle aerosolization compared with pre-procedure levels (mean increase 0.0869 particles/cm^3, 95%CI 0.029-0.144, p=0.005; 0.105 particles/cm^3, 95%CI 0.050-0.1599, p=0.001). The three simulation studies[22,23,30] all found evidence of droplet or aerosol formation during nasendoscopy and associated patient behaviours such as sneezing (see Table 5).

None of the studies provide evidence in patients with COVID-19 or other respiratory infections and each of the studies had some limitations. The measuring device (an optical particle sizer) used in the clinical observation was not able to detect the smallest particles and this study provided limited information about the experimental setup and sampling location with respect to ventilation. The cadaveric and healthy volunteer simulation studies did not account for patient factors such as nasal secretions, fever etc. and not all used robust measures or accounted for potential confounders (see Table 5).

Findings on suctioning for airway clearance (n=6 studies)

Three studies used a retrospective cohort design, of which one evaluated SARS-Cov-2 transmission among healthcare workers in the USA, and two SARS transmission among health care workers in Canada. Two simulation studies (one from Hong Kong[24] and one from the USA[29]) used non-human simulators to evaluate aerosol / droplet production and the final study involved a clinical observation of aerosol / droplet production among H1N1 patients in the UK. Heinzerling et al[25] found that among seven HCW who performed airway suctioning on an infected patient without applying transmission-based precautions (e.g. use of mask) none developed SARS-Cov-2 infection. In the retrospective studies on SARS patients[26] Loeb *et al* found that critical care nurses who assisted with suctioning before intubation of SARS patients were four times more likely to become infected than nurses who did not perform suction (RR 4.2 95%CI 1.58- 11.14, p=0.04). However, Raboud *et al* 2010 found no evidence of association of suction for airway clearance with SARS infection in a study of exposure of 624 nurses. In the two simulation studies[24,29] Chan et al found that coughing during oro-tracheal suctioning could produce substantial dispersion of potentially infected exhaled air[24]. A simulation study using fluorescein to evaluation contamination

associated with a range of healthcare activities, found that suctioning was not associated with increased concentration of fluorescein in air relative to other general care activities e.g. bathing, intravenous access, physical examination and no contamination was found on face or face shield during suctioning.[29] Finally, a clinical observation study on H1N1 pandemic patients found an increase in aerosol generation during respiratory/airway suctioning but this was not statistically significant (OR = 4.11 (0.50–34.0).[28] The particle size generated during suctioning were smaller than those collected during baseline but the difference was not significant.

Each study has limitations. The three transmission studies rely (at least in part) on participant recall to determine which procedures HCW performed, and as such are at risk of recall bias. These retrospective studies are also at high risk of confounding as HCW performed multiple procedures (not just suction for airway clearance) and it is unclear which (if any) are responsible for the infection, although Raboud *et al*[27] did adjust for this in a regression analysis, and HCW may have acquired the infection from another source. Second, two of the three studies on aerosol / droplet generation are simulations and as such it is not clear how these correspond to real-world conditions, for example breathing and nasal secretions, and there are also concerns about the appropriateness of measures used in these studies. Finally, the clinical observation on H1N1 patients provides no details on what type of respiratory suctioning was involved and there was considerable variation between and within individuals in the emission of aerosolised RNA.

Overview of systematic reviews

Two systematic reviews were identified that included primary research and addressed the review questions (Table 6).[33,34] One investigated the evidence for the risk of transmission of acute respiratory infections to healthcare workers caring for patient undergoing AGPs, including nasogastric tube insertion and suctioning.[33] Limited evidence was found, findings were based on the two studies already considered by this review[26,27] and it was conducted prior to COVID-19. The authors concluded that although both procedures might be associated with an increased risk of transmission the odds ratios were not statistically significant.

Thamboo et al[34] undertook a systematic review of potential AGPs in otolaryngology – head and neck surgery during the COVID-19 pandemic in order to inform clinical recommendations. The review found limited evidence in relation to nasoendoscopy and endoscopic surgery and identified some of the studies already included in this review. The authors made assumptions about the risk associated with different particles size, evidence was assessed and weighted and the limitations of basing recommendations on evidence from small, descriptive case-series experimental studies or retrospective cohort studies was recognised. The authors concluded that evidence for potential aerosols from nasal endoscopy was low and for treatment of epistaxis was moderate. Evidence for nasal electrocautery was not distinguished.

Interpretation

We identified and evaluated evidence for the generation of respiratory aerosols during nasogastric tube insertion, cardiopulmonary exercise and lung function tests, nasoendoscopy, swallowing assessment and oral suction and their association with risk of transmission of SARS-CoV-2 and similar respiratory infections.

The evidence is predominantly derived from experimental simulation studies which used optical particle counters or digital photography to measure respiratory particle dissemination or attempted to simulate droplets with fluorescein or aerosols with smoke. Some studies used cadavers or porcine tissue where the background effects of breathing and nasal secretions would not be accounted for, with only three studies[30,32,22] based on healthy volunteers where behaviour such as coughing and sneezing could be evaluated. These simulation studies had important limitations in terms of the reliability of the measurement method in accurately detecting a wide range of particle sizes, some did not adjust for background levels or position counters to capture exposure to the operator, and the extent to which the simulation reflects actual aerosol generation is unknown. Four studies based on clinical observation were more likely to reflect a real-life situation; one found a non-significant increase in aerosols associated with suctioning, two a significant increase in aerosols compared with baseline associated with sinonasal and endonasal

debridement, but another study found minimal spread of particles beyond the endonasal surgical field.

Although simulation studies provide some evidence of the potential for airborne respiratory particles to be generated from these procedures, the presence of aerosols does not prove an increased risk of transmission of respiratory viruses. In order to demonstrate a clinically significant risk of airborne infection, aerosols must contain enough infectious virus to enable an infective dose to reach the specific host cell tissue that the virus is able to infect.[36] The evidence needs to demonstrate a significant increase in aerosols compared with background levels and that the aerosols are able to carry virus and transmit infection.

Only one study on oral suctioning[28] set out to detect influenzas virus in respiratory particles but did not attempt culture to establish if the particles could transmit infection. Epidemiological evidence from studies that explored the risk of developing respiratory infection in personnel who performed the procedure is limited and only found for nasogastric tube insertion and suctioning. These studies did not demonstrate an association between performing these procedures and the risk of SARS, although the risk may be different in relation to SARS-CoV-2.

The potential for respiratory infections to transmit by an airborne route is dependent on a complex set of parameters which influence the generation and behaviour of respiratory particles. Conventionally, airborne particles have been distinguished as droplets which settle rapidly because of their mass, and aerosols which evaporate to form droplet nuclei and travel longer distances.[37,3] Droplets were perceived to be the primary risk of transmission when a susceptible person is in close proximity.[4,8]

However, it is now recognised that the dynamics are more complex and affected by a number of factors including force and volume of exhalation as well as humidity, temperature and airflow in the surrounding environment which affect the rate of evaporation and dissemination of particles.[6] Natural respiratory activities such as breathing and talking can generate a broad range of particle sizes, from submicron aerosols to large droplets. Using an expiratory droplet assessment kit (0.5 μm - 20 μm) on healthy volunteers,

Gregson et al (2020)[5] found an association between amplitude of speaking or singing and increased concentration of short-range aerosols but also a significant variation in particle emission between individuals. Indeed, results from different studies on the fluid dynamics of respiratory particles vary by orders of magnitude reflecting both the complexity of the phenomenon and approaches to measurement.[6]

One of the concerns related to the procedures included in this review was their tendency to induce coughing. The mechanism by which coughing generates respiratory particles involves high-speed airflow over the mucus lining the airway and this generates a higher concentration of respiratory particles compared with speaking.[7] The initial particle cloud has a high concentration of droplets which settle rapidly. The smaller particles remain in suspension and travel further. The evaporation of smaller droplets into droplet nuclei depends on the ambient temperature and relative humidity.[38] However, given the greater mass of droplets expelled by either coughing or speaking these particles contain a high proportion of the fluid, and therefore virus, expelled. The amount of virus expelled will also depend on the viral load which will vary depending on the severity of the infection and specific regions of the respiratory tract that are affected.[7]

The competing risks of more virus in larger droplets at lower concentration versus a higher concentration of smaller droplets with lower viral load have not been well studied for coughing. However, the risk of being exposed to an aerosol containing virus appears to be lower than the risk due to larger droplets at close range. The added risk of being exposed to a virus-containing aerosol particles from an aerosol generating medical procedure appears to be low relative compared with the general risk of exposure to expiration from a patient. In a light-scattering study the authors estimated that during 1 min of loud speaking at least 1,000 virion-containing droplet nuclei would be generated and remain airborne for more than 8 min. Nevertheless, at a saliva viral load of 7×10^6 copies per millilitre the probability that a 3µm droplet nucleus contains a virion is only 0.01%.[39] Viral emissions associated with coughing are likely to be considerably higher than for breathing[40] with more virus being contained in larger droplets, which present a greater risk during close contact rather than via longer range aerosols. Therefore, the risk of aerosol infection from patients in the

absence of AGPs is not fully understood and the additional risk posed by AGPs whether as aerosols or droplets, is difficult to distinguish from general patient interaction.

The generation of the aerosol is only one component of the chain of infection, with the quantity and stability of the virus and susceptibility of the host also being key to transmission.[6,36] The particle must be able to enter or be transferred onto the mucous membranes of the host and carry a sufficient number of viable virus to by-pass the host human defences, including the mucus coating the cell surface. Whilst experimental studies have explored the dynamics of respiratory particles, these viral and host parameters determining the risk of infection are less well understood. In addition, environmental factors such as the proximity of susceptible individuals and the duration of exposure, the size of the indoor environment and its ventilation, as well as hygiene practices and the presence of surfaces that play a role in indirect contact will also be important in transmission.

There are few other systematic evidence reviews that address these medical procedures. One was conducted prior to the COVID-19 pandemic. It informed the concepts of high risk AGPs and drew similar conclusions to our review in relation to nasogastric tube insertion and suctioning.[33] There is only one robust review related to SARS-CoV-2, this is focused on nas(o)endoscopy and, although did not identify all the evidence included in this review, drew similar conclusions.[34]

Overall, we identified an absence of evidence to suggest that these procedures are associated with additional risk of transmission of respiratory viruses beyond standard patient interactions. For pulmonary function tests, very low levels of particle emission were detected in the one study on lung function tests. Coughing was associated with emission of large particles which are more likely to equate to droplets than aerosols. Similarly, two simulation studies found no significant increase in aerosol generation or contamination of the face associated with suctioning of the respiratory tract. Findings from simulation studies on nasoendocopy suggested a significant increase in aerosols but findings were inconsistent, probably reflecting the use of different models (cadaveric, porcine or human volunteer) and lack of robust measures to detect particles, and absence of baseline

measures in some cases, and uncertainty about whether fluorescein and smoke are adequate surrogates for the generation of human respiratory particles. In addition, these simulation studies are difficult to equate to clinical conditions and did not account for patient factors such as coughing and were vulnerable to confounding. The limited evidence available from studies of virus emission or evidence of transmission associated with conducting these procedures did not demonstrate a risk of transmission, although their retrospective design makes them vulnerable to bias and confounding. Given the absence of evidence it is not possible to establish a clear absence of risk associated with these procedures.

Coughing may be a risk factor for transmission. However, although this has been investigated experimentally in terms of aerosol generation, an association with infection transmission has not been demonstrated. Aerosol generation (<10um) associated with coughing appears to be at a relatively low level but is highly variable. Epidemiological evidence suggests that the specific characteristics of the patient are a critical factor in driving transmission as a large proportion of transmission to both other patients and staff appears to be related to only a small number of patients.[42,43] Exposure during early stage in infection when viral load is highest is a key factor in driving risk and needs to be considered in terms of identifying risk to healthcare workers.[43]

The most recent WHO guidance on the use of masks in healthcare settings acknowledged that whilst respirators are recommended primarily for settings where AGPs are performed, some healthcare workers have strong preferences about having the highest perceived protection. However, whilst personal protective equipment such as N95/FFP3 respirators have a role to play in protecting against inhalation of aerosolised particles, administrative and engineering controls remain priority components of infection prevention and control. Strategies to ensure that patients with SARS-CoV-2 are segregated to allow non-urgent procedures to be conducted when no longer infectious and that procedures are conducted in well ventilated areas are key to mitigating the potential risk from aerosols.[2]

Evidence suggests that the risk of transmission of SARS-CoV-2 to healthcare workers may be determined by a more complex range of factors than purely the generation of aerosols.[33,44]

Aerosols have been assumed to be the explanation for the association between a small number of respiratory tract procedures such as tracheal intubation, non-invasive and manual ventilation, and risk of transmission to healthcare workers performing them.[33] This potential route of transmission has subsequently been applied to a wider set of procedures, for which expert consensus has assumed a similar risk of exposure to respiratory aerosols, and these are defined as high risk AGP.[1,45] However, evidence for aerosols being generated during some procedures designated as AGP is absent or equivocal.[41,44] It is therefore possible that other factors such as very close and prolonged contact with respiratory secretions might play a role in increasing the risk of transmission.[33,44] Uncertainty about the link between medical procedures and risk of transmission to healthcare workers is demonstrated by the significant inter-country variation in designation of medical procedure as AGPs.[46]

The paradigm for AGPs needs further consideration to better combine evidence from aerosol and infection prevention and control science. More research is required to determine the characteristics of both medical procedures and patients that increase the risk of transmission in order to better target precautions to mitigate the risk.

Limitations of review

This review was limited in scope and because undertaken within a short timeframe was restricted to publications in PubMed. However, this would be expected to capture the main publications on this topic and references from the included studies and other systematic reviews were assessed to help mitigate this. Findings related to other respiratory viruses may not be comparable with SARS-CoV-2 because of difference in transmission dynamics.

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Figure legends

Figure 1: Elements considered in the risk of bias evaluation

Notes. AG = aerosol generating; AGPs = aerosol generating procedures; AGB = aerosol generating behaviours; PPE = personal protective equipment. The rectangles labelled RQ1 and RQ2 show the parts of the model that were explored by research question 1 and research question 2, respectively. The orange area of overlap between these rectangles indicates the intersection of the foci of the two research questions in relation to aerosol production. RQ1: Does evidence suggest that medical procedures which induce coughing or involve respiratory airway suctioning result in infectious aerosol production? RQ2: If yes, what is the associated risk of transmission of SARS-CoV-2? The grey box labelled "Not covered in the literature" refers to the evidence base at the time of the searches were conducted (Oct, 2020).

Figure 2: PRISMA diagram

Web Appendix 1: Search terms

Pubmed Search (legacy interface)

6/10/20

(((((Deglutition Disorders/diagnosis[mh] OR ((videofluoroscopy[Title/Abstract] OR fluoroscopy[Title/Abstract] OR endoscopy[Title/Abstract] OR endoscopic[Title/Abstract] OR endoscopic[Title/Abstract] OR Laryngoscop*[Title/Abstract]) AND (swallow[Title/Abstract] OR swallowing[Title/Abstract] OR nasal[Title/Abstract] OR sinonasal[Title/Abstract] OR nose[Title/Abstract] OR dysphagia[Title/Abstract])) OR (dysphagia[Title/Abstract] AND (assess[Title/Abstract] OR examine[Title/Abstract] OR assessment[Title/Abstract] OR assessing[Title/Abstract] OR examination[Title/Abstract] OR procedure[Title/Abstract] OR procedures[Title/Abstract])) OR ((Otorhinolaryngologic Surgical Procedures[Title/Abstract] OR Otorhinolaryngologic Surgical Procedures[mh]) AND (swallow[Title/Abstract] OR swallowing[Title/Abstract] OR nasal[Title/Abstract] OR sinonasal[Title/Abstract] OR nose[Title/Abstract] OR dysphagia[Title/Abstract])) OR Intubation, Gastrointestinal[Mesh] OR Rehabilitation of Speech and Language Disorders[Mesh] OR airway clearance*[Text Word] OR "clear airways"[Text Word] OR (clear*[Text Word] airway*[Text Word]) OR "clearing airways"[Text Word] OR "clearing airway"[Text Word] OR airway control[Title/Abstract] OR suction*[Title/Abstract] OR dysphagia assessment*[Text Word] OR swallow*[Text Word] OR cough reflex test*[Text Word] OR mechanical aspiration[Title/Abstract] OR ((reflex OR reflexes OR reflexive)[Title/Abstract] AND coughing[Title/Abstract]) OR forceful coughing[Text Word] OR prolonged coughing[Text Word] OR fibreoptic endoscopic evaluation*[Text Word] OR Suction[Mesh] OR Airway Extubation[mh] OR Airway Management[mh:noexp] OR airway control[Title/Abstract] OR airway management[Title/Abstract])) OR (Respiratory Function Tests[Mesh] OR Exercise Test[Mesh] OR Spirometry[Mesh] OR respiratory function test*[Text Word] OR pulmonary function test*[Text Word] OR lung function test*[Text Word] OR exercise test*[Text Word] OR fitness test*[Text Word] OR arm ergometry test*[Text Word] OR step test*[Text Word] OR stress test*[Text Word] OR treadmill test*[Text Word] OR eurofit test*[Text Word] OR bicycle ergometry test*[Text Word] OR walk test*[Text Word] OR spirometr*[Text Word] OR bronchospirometr*[Text Word])) OR (Diagnostic Techniques, Respiratory System [mh] OR (((Pulmonary[Title/Abstract] OR respiratory[Title/Abstract] OR lung[Title/Abstract]) AND Function Test*[Title/Abstract]) OR Exercise tolerance test*[Title/Abstract] OR cardiac physiology[Title/Abstract]) OR (((((ESOPHAGUS[mh] AND INTUBATION[mh]) OR Intubation, Intratracheal[mh] OR intubation[Title/Abstract] OR endoscopic[Title/Abstract] OR endoscopy[Title/Abstract]) AND (nose OR nasogastric OR nasal OR sinonasal OR naso gastric)) OR (Natural Orifice Endoscopic Surgery[MeSH Terms] AND (nose[MeSH Terms] OR nasal[Title/Abstract] OR sinonasal[Title/Abstract] OR nose[Title/Abstract] OR nasogastric[Title/Abstract] OR naso gastric[Title/Abstract])) OR ((cautery[MeSH Terms:noexp] OR cautery[Title/Abstract]) AND (nose[MeSH Terms] OR Nasal Surgical Procedures[MeSH Terms] OR nasal[Title/Abstract] OR sinonasal[Title/Abstract] OR nose[Title/Abstract])) OR (Nasoendoscopy[Title/Abstract] OR Naso endoscopy[Title/Abstract] OR nasogastric tube*[Text Word] OR "naso gastric tube"[Text Word] OR "naso gastric tubes"[Text Word] OR nasogastric intubation*[Text Word] OR gastrointestinal intubation*[Text Word])))))) AND ((((("unexpected exposure"[Text Word] OR "disease transmission"[Text Word] OR "Infection Transmission"[Text Word] OR "Infection Transmission" OR "Pathogen Transmission"[Text Word] OR "risk of transmission" OR "viral transmission"[Text Word] OR "cross infect"[Text Word] OR "cross-infect"[Text Word] OR "cross infects"[Text Word] OR "cross-infects"[Text Word] OR "cross infection"[Text Word] OR "cross-infection"[Text Word] OR "cross infections"[Text Word] OR "cross-infections"[Text Word] OR "droplet

spread"[Text Word] OR "droplet spreading"[Text Word] OR droplet emission*[Text Word] OR aerosol[Text Word] OR aerosols[Text Word] OR aerosoli*[Text Word] OR droplets[Text Word] OR (droplet[Text Word] AND splatter*[Title/Abstract] OR spread*[Title/Abstract]) OR droplet exposure*[Text Word] OR "viral particle"[Text Word] OR "airborne" OR "air borne" OR particulate[Title/Abstract] OR particulates[Title/Abstract] OR "Airborne particulate"[Text Word] OR "Airborne particulates"[Text Word] OR "particulate generation"[Title/Abstract] OR "particle generation"[Title/Abstract] OR airborne[Title/Abstract] OR transmission[MeSH Subheading] OR guidance*[ti] OR guideline*[ti] OR recommend*[ti] OR risk*[ti]) AND (Coronavirus[mh] OR Coronavirus Infections[mh] OR coronavirus* or "corona virus" or "corona viruses" or OC43 or NL63 or 229E or HKU1 or HCoV* or ncov* or covid* or sars-cov* or sarscov* or Sars-coronavirus* or "Severe Acute Respiratory Syndrome" OR SARS OR "severe acute respiratory syndrome"[mh] OR "severe acute respiratory syndrome" OR "Middle East Respiratory Syndrome Coronavirus"[mh] OR "middle east respiratory syndrome" OR "middle east respiratory syndromes" OR "MERS-CoV" OR Mers OR "Middle Eastern Respiratory Syndrome" OR "Middle Eastern Respiratory Syndromes" OR MERSCoV* OR "COVID-19" or "2019-nCoV" or "SARS-CoV-2" OR ((coronavirus*[Title/Abstract] OR coronovirus*[Title/Abstract] OR "2019-nCoV"[Title/Abstract] OR "COVID-19"[Title/Abstract] OR "COVID 19"[Title/Abstract] OR "HCoV-19"[Title/Abstract] OR CoV[Title/Abstract] OR ncov[Title/Abstract] OR "SARS-CoV-2"[Title/Abstract] OR (ncov*[Title/Abstract] AND wuhan[Title/Abstract]) OR "severe acute respiratory syndrome"[Title/Abstract] OR "sudden acute respiratory syndrome"[Title/Abstract] OR SARS[Title/Abstract] OR MERS[Title/Abstract] OR "Middle East Respiratory Syndrome"[Title/Abstract] OR influenza[Title/Abstract] OR flu[Title/Abstract]) OR ((("Coronavirus"[Mh] OR "Coronavirus Infections"[Mh] OR "Middle East Respiratory Syndrome Coronavirus"[Mh]) OR "Severe Acute Respiratory Syndrome"[Mh]) OR "Influenza, Human"[Mh])))) OR ((infect[Title/Abstract] OR infecting[Title/Abstract] OR infectious[Title/Abstract] OR infect*[Title/Abstract] OR exposure[Title/Abstract] OR transmission[Title/Abstract] OR transmission[Title/Abstract] OR "disease transmission"[Title/Abstract] OR "Infection Transmission"[Title/Abstract] OR "Infection Transmission"[Title/Abstract] OR "Pathogen Transmission"[Title/Abstract] OR "risk of transmission" OR "viral transmission"[Text Word] OR cross infect*[Text Word] OR cross-infect*[Text Word]) AND (health personnel[mh] OR "healthcare worker"[Title/Abstract] OR health worker*[Title/Abstract] OR health care worker*[Title/Abstract] OR "health care staff"[Title/Abstract] OR "healthcare staff"[Title/Abstract] OR ENT specialist*[Title/Abstract] OR physiotherapist*[Title/Abstract] OR therapist*[Title/Abstract] OR "health personnel" [Title/Abstract] OR "health care personnel" [Title/Abstract] OR "healthcare personnel"[Title/Abstract] OR clinician*[Title/Abstract] OR health professional*[Title/Abstract] OR healthcare professional*[Title/Abstract] OR health care professional*[Title/Abstract] OR Otorhinolaryngologists[Title/Abstract] OR Otolaryngologists[Title/Abstract] OR surgeons[Title/Abstract] OR "surgical staff"[Title/Abstract])) OR (("unexpected exposure" OR transmission[Title/Abstract] OR "disease transmission" OR "Infection Transmission" OR "Infection Transmission" OR "nosocomial infection" OR "hospital transmission" OR "nosocomial transmission" OR "Pathogen Transmission" OR "risk of transmission" OR "viral transmission" OR "cross infect" OR "cross-infect") AND (risk[Title/Abstract] OR risks[Title/Abstract] OR "risk factors"[mh])) OR ("Cross Infection"[mh] OR "Disease Transmission, Infectious"[mh] OR Occupational Exposure[mh]))) AND ((Aerosols[MeSH Terms] OR (droplet[Title/Abstract] OR droplets[Title/Abstract] OR cough*[Title/Abstract] OR sputum*[Title/Abstract] OR "respiratory secretion"[Title/Abstract] OR "respiratory secretions"[Title/Abstract] OR aerosol*[Text Word] OR airborne[Text Word] OR AGP[Text Word] OR AGPs[Text Word] OR "Aerosols"[Mesh] OR "Air Microbiology"[mh] OR particulates OR "particulate generation"[Title/Abstract] OR "particle generation"[Title/Abstract]))) AND ("2003"[Date - Publication] : "3000"[Date - Publication]))

Table 1: Procedures of concern in relation to generation of infectious aerosols

Nasogastric tube insertion

Cardiopulmonary and lung function tests, cardiopulmonary exercise test, spirometry, cardiac physiology procedures

Swallowing assessment related to dysphagia including endoscopic and fluoroscopy

Suction of the upper airway in the context of airway clearance

Endoscopic sinus surgery, cautery and nasoendoscopy (nasendosocopy)

Tables 1 to 6: Evidence tables for included studies

Table 1: Primary research on nasogastric tube insertion (n=2 studies)

	Study details	Procedures and measures	Findings	Study limitations / contribution
1	**Study:** Loeb (2004)[26] **Country:** Canada **Aim:** *"To determine risk factors for SARS among nurses who worked in two critical care units in a Toronto hospital."* **Design:** Retrospective cohort study	**Procedure(s) performed:** *On:* SARS patients (n=3) *By:* Usual clinician (Nurses) (n=32) *Where:* Hospital ward / room *Procedure repetitions:* n=8 **Outcome measures:** *Measure:* Virus transmission *Method:* Confirmed by antibody test.	**Key finding:** No evidence of association of nasogastric tube insertion with SARS infection. **Details:** 33% of nurses who undertook nasogastric tube insertion were infected with SARS (2/6 nurses) compared to 23% of nurses who did not undertake nasogastric tube insertion (6/26 nurses). Relative risk 1.44; CI 95% 0.38 to 5.47; P value 0.62. *Note: The authors report that of the 32 nurses who entered a SARS patient's room at least once 23 consistently wore a mask (either surgical or N95) whilst the remaining 9 did not. There is no specific information about mask use during nasogastric tube insertion.*	**Is the study a reasonable representation of real-world clinical practice?** Yes: clinically-based evaluation. **Are measurement tools appropriate / robust?** No: Risk of recall bias; procedure data are in part collected via interview and depend on how accurately nurses can recall what they did. **Does the study design control for potential confounders?** No: Nurses performed multiple procedures, including high risk AGPs, so unclear which (if any) are responsible for infections. No comparison of how much time nurses spend patient's room. Nurses may have been infected by another source although SARS was not disseminated in the local community. **Other concerns?** Small sample size.
2	**Study:** Raboud (2010)[27] **Country:** Canada **Aim:** *"To identify risk factors associated with transmission of SARS-CoV from patients requiring intubation to HCWs involved in their care."*	**Procedure(s) performed:** *On:* SARS patients who were intubated (n=45) *By:* Usual clinician (various HCW) (n=624) *Where:* Hospital ward / room *Procedure repetitions:* n=47	**Key finding:** No evidence of association of nasogastric tube insertion with SARS infection. **Details:** 8% of nurses who undertook nasogastric tube insertion of nurses were infected with SARS (2/26 nurses) compared to 8% who did not undertake nasogastric tube insertion	**Is the study a reasonable representation of real-world clinical practice?** Yes: clinically-based evaluation. **Are measurement tools appropriate / robust?** No: Risk of recall bias. Procedure data in-part from HCW recall – interviews conducted up to 10 months post-procedure. Patient hospital records used to confirm when possible. **Does the study design control for potential confounders?** No: HCW didn't necessarily perform procedure – considered 'exposed' if they reported being in room while patient received

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study limitations / contribution
	Design: Retrospective cohort study	**Outcome measures:** *Measure:* Virus transmission *Method:* Confirmed by antibody test or met case definition.	(45/598 nurses). Fishers exact test p value = 0.99. In the multivariate logistic regression model (to account for correlation among HCWs caring for same patient) nasogastric tube insertion not found to be an independent predictor of SARS infection. *Note: HCWs who contracted SARS were "more likely to have used less effective methods of respiratory protection while in a patient's room (p= .04)". There is no specific information about mask use during nasogastric tube insertion.*	procedure. HCW perform multiple procedures so unclear which (if any) are responsible for infection – although adjusted for in logistic regression. No information on duration of procedures, use of PPI in relation to specific procedures, length of time spent in patients' room. HCW may have been infected by another source although SARS was not disseminated in the community. **Other concerns?** Limited evidence re nasogastric tube.

Tables 1 to 6: Evidence tables for included studies

Table 2: Primary research on lung function testing (n=1 study)

	Study details	Procedures and measures	Findings	Study limitations / contribution
1	**Study:** Greening (2020)[32] **Country:** UK **Aim:** To determine the mass of small droplets exhaled at varying flow rates and during different respiratory manoeuvres. **Design:** Simulation in healthy volunteers using particle counter **Evidence:** - Does procedure generates aerosols - Do patient behaviours generate aerosols	**Procedure(s) performed:** *Procedure(s) evaluated:* - Tidal breathing - Forced expiratory volume - Slow vital capacity (SVC) following inspiration from functional residual capacity - SVC following inspiration from residual capacity *Patient behaviour(s) evaluated:* - Cough *Device(s) evaluated: N/A* *On:* Healthy volunteers (n=33) *By:* Not reported. *Where:* Not reported. *Procedure repetitions: n*=102 **Outcomes measured:** *Measure:* Droplet emission *Method:* Optical particle counter (Particles in Exhaled Air (PExA)).	**Key finding:** "Small droplet emission varies for different breath manoeuvre performed during PFT [pulmonary function tests], with very low production in TV [tidal volume] and sVC from FRC [functional residual capacity] and low production during FEV [forced expiratory volumne]" "Coughing is associated significant increase in particles." **Details:** *Tidal breathing:* There was minimal increase in particle mass during tidal breathing compared with background noise (median mass per litre of breath 0.09ng/l [IQR 0.09]) *SVC (functional residual capacity):* Median mass per litre of breath 0.4ng/l. *Forced capacity volume:* A higher particle mass production than SVC following functional residual capacity (+150%, 95%CI 10-470, P = .03). *SVC (residual capacity):* A significant increase in particle mass was seen with SVC following inspiration from residual capacity compared to SVC from functional residual capacity (+470%, 95%CI 150-1190, P < .01). Cough: Coughing resulted in the highest mass of exhaled particles compared with all other manoeuvres, with a 640% (95%CI 230-1570, P < .01) increase compared to Slow vital capacity following inspiration from functional residual capacity.	**Is the study a reasonable representation of real-world clinical practice?** Unclear: Performed with 'healthy volunteers', unclear how aerosol production might be affected in those with lung conditions or with a viral infection. Also authors note 'The manoeuvres in this study do not meet current ERS/ATS spirometry standards.' Most lung function laboratories will use in-line filters which would effectively filter airborne particles during these tests. **Are measurement tools appropriate / robust?** Unclear: Authors note that 'the PExA system registers mostly small droplets from the small airways, and virus are likely to be present in both upper and lower respiratory droplets.' The measurement of particle mass means no data about particle size. **Does the study design control for potential confounders?** Yes: Manoeuvres were performed using particle free HEPA filtered inspiratory air, but no particle filter between exhalation and sampling.

Tables 1 to 6: Evidence tables for included studies

				The authors note that manoeuvres also included a breath hold before exhalation which may result in lower flow rate and particle release.

Table 3: Primary research on endoscopic sinus surgery (n=9 studies)

	Study details	Procedures and measures	Findings	Study contribution / limitations
1	**Study:** David (2020)[15] **Country:** USA **Aim:** To *"describe our experience developing the negative-pressure otolaryngology viral isolation drape (NOVID) to reduce aerosol and droplet spread in and around the surgical field."* **Design:** Clinical observation using fluorescein	**Procedure(s) performed:** *Procedure(s) evaluated:* - microdebrider - drilling - cautery *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated:* - negative pressure isolation drape *On:* Patients with unknown COVID-19 status (n=4) *By:* Usual clinicians (surgeon, nurse, anaesthetist) (n=not stated) *Where:* Operating theatre *Procedure repetitions:* microdebrider (n=2), drilling (n=2), cautery (n=2) **Outcomes measured:** *Measure:* - Aerosol presence - Aerosol spread *Method:*	**Key finding(s):** "Our cases demonstrated there is minimal spread of fluorescein beyond the immediate surgical field." **Details:** *Droplets on patient:* We found very little contamination of droplets on the patient. In all cases, we found fluorescent dye at sites round the nares and on the wipe placed on the patient's chest. *Droplets on HCW:* A few droplets along the abdomen region and in one case a single droplet on the surgeon's arm. The scrub nurse had large droplets >5 mm on the abdomen region. *Droplets in operating field:* Droplet spread where the instruments or cottonoids were placed. Single droplet on the vertical drape "wall" at the foot of the patient (about 4ft from surgeon).	**Is the study a reasonable representation of real-world clinical practice?** Yes: real-world clinical observation involving live patients. **Are measurement tools appropriate / robust?** No: No information on how droplets are identified or by who. **Does the study design control for potential confounders?** No: Potential for false positive findings due to use of 'epinephrine soaked cottonoids'. No control group to compare droplet spread without NOVID system. **Other concerns?** Small study. Limited details on outcomes, only presented descriptively. Assessments undertaken before and after surgery is complete so unable to determine which of the nasendscopic procedures generated droplets.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Ultraviolet examination of fluorescein droplets on surgical drapes and gowns. Note: particles were captured by connecting tubing to the smoke evacuator manifold port on a Neptune suction system to provide a negative pressure chamber.		
2	**Study:** Guderian (2020)[16] **Aim:** *"To develop an experimental setup for the simultaneous assessment of aerosol and particle formation in various typical ENT interventions."* **Country:** Germany **Design:** Simulation using 'porcine soft and hard tissues' using video recording	**Procedure(s) performed:** *Procedure(s) evaluated:* - non-powered instrument (without suction) - non-powered instrument (with suction) - Laser treatment - drilling - cautery *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated:* - Suction *On:* fresh porcine tissue (bone and muscle) in a test chamber (n=N/A) *By:* Not reported (n=not reported) *Where:* Not reported *Procedure repetitions:* n=ADD **Outcomes measured:** *Measure:*	**Key findings:** "In contrast to sole mechanical stress with passive instruments, all active instruments (laser, drilling and electrocoagulation) released particles and aerosols." **Details:** *Non-powered instrument without suction:* No particle or aerosol formation detected. *Non-powered instrument with suction:* No particle or aerosol formation detected. *Laser treatment:* Droplets – A highly directed ejection of very fine droplets was observed under microscope. Aerosols - Laser-induced aerosol formation "considerable and surpassed all other surgical intervention techniques". *Drilling:* Droplets – "clearly detectable particles". Aerosols – "effect represented a spray mist rather than a gaseous aerosol." *Cautery:* Droplets – "strongest effect in comparison to all other intervention techniques". Aerosols – "considerable aerosol formation".	**Is the study a reasonable representation of real-world clinical practice?** No: Experimental simulation, influence of breathing and nasal secretions not accounted for. Test chamber does not correspond to the spatial dimensions of an oral or nasal cavity. Experiments undertaken for 3 minutes only – unclear if consistent with real-world procedure duration. **Are measurement tools appropriate / robust?** Unclear: Good reliability – "To eliminate inter- and intraobserver variability, measurements were performed fully automatic with different computer based algorithms". But unclear how sensitive video footage will be to capture aerosols, particularly smallest size. **Does the study design control for potential confounders?** Yes:

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		- Droplet size - Droplet number - aerosol density *Method:* Droplets photodocumented with a digital microscope (20 × magnification), software used to assess findings. Aerosols recorded with a Full-HD camera at 25 frames per second. Video post-processed frame by frame, software used to assess findings.		Procedures performed and measures taken in 'test chamber' so outcomes are highly likely to be attributable to procedure. Test chamber removes influence of ventilation. Procedure duration reported and consistent across interventions. **Other concerns?** Limited details re computer software programme.
3	**Study:** Jones (2020)[17] **Country:** UK **Aim:** To investigate *"the potential for a simple negative-pressure mask technique to reduce the risk of intraoperative aerosol and droplet exposure for theatre staff."* **Design:** Cadaveric simulation using fluorescein	**Procedure(s) performed:** *Procedure(s) evaluated:* - Rigid endoscope (with suction mask) - Microdebrider (with / without suction mask) - Drilling (with and without suction mask) - External activation of powered instruments (within suction mask) *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated:* - negative pressure mask *On:* Cadaver (n=1) *By:* Usual clinician (surgeon) (n=1) *Where:* Laboratory	**Key findings:** "The use of a negative-pressure mask technique resulted in 98% reduction in the fine particulate aerosol simulation and eliminated larger respiratory droplet spread during simulated ESS [endoscopic sinal surgery], including during external drill activation." **Details:** *Rigid endoscope:* "Significant emission of aerosolized particles without a mask [no procedure performed]". Use of suction mask "resulted in a 98% reduction […] addition of an endoscope to the setup did not alter this." *Microdebrider:* "No fluorescein droplets were observed with or without the negative-pressure mask during the simulation of powered microdebrider-assisted ESS." *Drilling:* "External droplet spread was observed up to the 10-cm mark during the powered drilling	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation, influence of breathing and nasal secretions not accounted for. **Are measurement tools appropriate / robust?** Unclear: Unclear how appropriate smoke is as a proxy for aerosols. No information on how droplets are identified or by who. **Does the study design control for potential confounders?** Unclear: A noise reference image [for smoke scenario] was captured before each scenario and adjusted for in analysis. The drape [droplet scenario] was washed down between each scenario but unclear

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Procedure repetitions: Each procedure performed once. **Outcomes measured:** *Measure:* - Droplet presence - Aerosol presence *Method:* Aerosols simulated using smoke and captured by digital camera; findings assessed by software. Droplets measured using ultraviolet examination of fluorescein on surgical drape covering cadaver.	simulation, despite the use of a cutting burr with integrated suction […] when the procedure was repeated with the negative pressure mask, no contamination was observed" *External activation of powered instruments:* "We activated the drill external to the cadaver but within the mask instrument aperture, both with and without negative pressure. Significant contamination was observed within the mask, but none was evident externally."	if checked with ultraviolet for residual droplets. **Other concerns?** Small study.
4	**Study:** Murr (2020a)[31] **Country:** USA **Aim:** *"To provide greater understanding of possible SARS-CoV-2 exposure risk during endonasal surgeries."* **Design:** Clinical observation using particle counter.	**Procedures performed:** *Procedure(s) evaluated:* - Non-powered instrument with suction - microdebrider - drilling *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated: N/A* *On:* COVID-19 negative patients. *By:* Usual clinician(s) (surgeon, nurse, anaesthetist). *Where:* Standard operating theatre. *Procedure repetitions:* 133 measures during N=5 surgeries: 3 skull based tumour, 1 orbital abscess and 1 functional endoscopic sinus surgery	**Key findings:** Drilling and microdebrider use, but not non-powered instrumentation, were associated with a significant increase in airborne particle concentrations. The increased concentrations were localized to the area of the operating surgeon. **Details:** *Non-powered instrumentation:* Significant increases in airborne particle concentration were not seen for non-powered instrumentation with suction (mean change = 716 p/ft3; p=0.340). *Microdebrider:* Significant increases in airborne particle concentration were measured at the surgeon position with the microdebrider (mean change =1825 p/ft3; p=0.001) Drilling: Significant increases in airborne particle concentration were measured at the surgeon	**Is the study a reasonable representation of real-world clinical practice?** Yes: live patient procedures in standard operating room. **Are measurement tools appropriate / Robust?** Unclear: Particle sizer calibrated to national standards; repeated measures, 133 measurements made during 5 surgeries. 73% of particles were near the lower limit of detection (3 um) where counting efficiency of instrument is 50% and the size distributions indicate that a significant fraction is less than 0.3 µm. **Does the design control for potential confounders?** Yes: Particle

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Outcomes measured: *Measure(s):* - *Aerosol concentration* - *Aerosol spread* (measurements collected at 3 positions: 1) the operating surgeon position, 2) the circulating nurse position, and 3) the anaesthesia provider position.) *Method:* Optical particle counter / sizer (Extech VPC300).	position with the drill (mean change = 2418p/ft3; p=0.001), *Non-surgeon positions:* Particle concentration did not significantly increase at the anaesthetist position or the nurse position with any form of instrumentation.	concentrations compared to pre-instrumentation levels. **Other concerns?** "The localized particle effect described in this study quantifies aerosol concentrations at distinct positions, and therefore is limited in describing exposure risk to staff who move about freely in the operating room, such as the nurse."
5	**Study:** Sharma (2020a)[19] **Country:** USA **Aim:** *"To quantify the number concentrations of aerosols generated during rhinologic surgery with and without interventions involving 3 passive suction devices."* **Design:** Cadaveric simulation with particle counter	**Procedure(s) performed:** *Procedure(s) evaluated:* - Non-powered instrument - Microdebrider - Drilling - Electrocautery - Ultrasonic aspirator *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated: N/A* - rigid suction - suction ring - surgical smoke evacuation system *On:* Cadaver head specimen (n=1) *By:* Usual clinician (rhinologist) (n=1) *Where:* Dedicated surgical laboratory	**Key findings:** All procedures "generated a statistically significant increase in the number concentration of aerosols […] 3 passive suction interventions all significantly reduced aerosols in multiple size ranges for all the tested surgical conditions. Among these, the surgical smoke evacuation system appeared to be the most effective in mitigating aerosol generation." **Details:** *Non-powered instrument:* FESS [Functional Endoscopic Sinus Surgery] with nonpowered instrumentation (cold FESS) generated a statistically significant increase in total aerosols (mean difference, 1.29 particles/cm3; P \ .001), and there was a significant increase in the size range of 0.30 to 0.37 µm (P <.001). Use of the surgical smoke evacuation system resulted in significantly decreased aerosol concentrations (P <.001) as compared with FESS with no suction (P = .27) and	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation, influence of breathing and nasal secretions not accounted for. **Are measurement tools appropriate / robust?** Unclear: Particle sizer which was calibrated before and after sampling. However, the lower detection limit of the aerosol instrument was 0.3 µm below which many particles are likely to reside given that 0.3 µm contained the largest fraction of particles measured. **Does the study design control for potential confounders?** Yes: Prior to each experiment, background aerosol concentration was

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Procedure repetitions: Non-powered instrument and microdebrider 5 minutes each, drilling, electrocautery and aspirator 2 minutes each. **Outcomes measured:** *Measure:* - Aerosol concentration - Aerosol size *Method:* Optical particle counter / sizer (OPS 3330; TSI Inc).	as compared with FESS with the ring suction (P = .07). *Microdebrider:* There was no significant difference in total particle concentration during FESS performed with powered suction microdebrider as compared with baseline (mean difference, –0.025 particles/cm3; P = .83). Both suction interventions resulted in decreased aerosol concentrations at larger particle sizes but increased concentrations at smaller particle sizes as compared with the suctioning microdebrider alone *Drilling*: High-speed endonasal powered drilling of the sphenoid rostrum generated a significant increase in total aerosol concentration as compared with baseline (mean difference, 11.44 particles/cm3; P<.001) with significant increases of particles ranging from 0.30 to 2.69 µm. All 3 suction intervention conditions had significantly decreased aerosol concentrations as compared with no suction (P<.001). *Cautery:* Needle tip electrocautery of the nasal mucosa along the septum and inferior turbinate without suction demonstrated a significant increase in total aerosol concentration as compared with baseline (mean difference, 1.58 particles/cm3; P<.001). Rigid suction plus the surgical smoke evacuation system resulted in the greatest decrease in aerosol generation, with concentrations significantly lower than rigid suction alone in 10 particle size ranges (P = .015).	measured every second for 1 minute. HEPA filtration system used between experiments to return aerosol level to baseline and allow for detection of low particle concentrations. Particle sizer positioned to accurately represent the aerosol risk to the operating surgeon and surgical technologist.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
			Ultrasonic aspirator: The use of an ultrasonic aspirator on frontal bone resulted in significant increases in total aerosol concentration (mean difference, 4.41 particles/cm3; P < .001). Conditions from both the rigid suction plus suction ring and the rigid suction plus surgical smoke evacuation system had significantly decreased aerosol concentrations as compared with the rigid suction alone. Surgical evacuation smoke system was used with rigid suction for drilling / cautery but not for the nonpowered instrument FESS and microdebrider.	
6	**Study:** Sharma (2020b)[20] **Country:** USA **Aim:** *"To investigate droplet and splatter patterns resulting from common endoscopic endonasal procedures."* **Design:** Cadaveric simulation using fluorescein	**Procedure(s) performed:** *Procedure(s) evaluated:* - Nasal endoscope - Non-powered instrument - microdebrider - drilling (with and without suction) - external activation of powered instruments - ultrasonic aspirator *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated:* - suction used with drilling *On:* Cadaver head specimen (n=2)	**Key findings:** "Our results indicate that there is very little droplet generation from routine rhinologic procedures. The droplet generation from drilling was mitigated with the use of concurrent suction. Extreme caution should be used to avoid activating powered instrumentation outside of the nasal cavity, which was found to cause droplet contamination." **Details:** *Nasal endoscope:* No observable fluorescein droplets were noted in the measured surgical field in any direction. *Non-powered instrument:* No observable fluorescein droplets were noted in the measured surgical field in any direction for FESS	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation, influence of breathing and nasal secretions not accounted for. **Are measurement tools appropriate / robust?** Unclear: All measurements were performed independently by 3 evaluators. The authors note that instead of a complete 360-degree assessment, the design model allowed for measurements only in the cardinal directions surrounding the specimen. Measurement technique is not compared to other more standard assessments.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		By: Usual clinician (surgeon) (n=1) *Where:* 'dedicated surgical laboratory' *Procedure repetitions:* n=1 for most procedures, n=2 for non-powered instrument and microdebrider **Outcomes measured:** *Measure(s):* - Droplet number - Droplet size - Droplet distance *Method:* Ultraviolet light examination of fluorescein around operating table and on surgeon's chest and face shield. Evaluators counted and recorded the number, size, and distance of any illuminated fluorescent spots.	[functional endoscopic sinus surgery] performed with cold [non-powered] instrumentation. *Microdebrider:* No observable fluorescein droplets were noted in the measured surgical field in any direction for septoplasty with microdebrider-assisted turbinoplasty. Limited droplet spread was noted under microdebrider FESS (2 droplets within 10 cm of cadaver head, all less than 1 mm in size). *Drilling (with and without suction):* No observable fluorescein droplets were noted in the measured surgical field in any direction for drilling of the sphenoid rostrum with a cutting burr, drilling of the frontal beak with a diamond burr, drilling of the sphenoid rostrum with a diamond burr with concurrent suction and drilling of the frontal beak with concurrent suction. Limited droplet spread was noted under drilling of the sphenoid rostrum with a diamond burr (8 droplets within 12 cm of cadaver head, all less than \1 mm in size) and drilling of the frontal beak with a cutting burr (5 droplets within 9 cm of cadaver head,\1 mm in size). The use of a concurrent suction while drilling resulted in no contamination. *External activation of powered instruments:* Limited droplet spread was noted under *control* condition of the drill placed outside the nose (0.5 cm droplet on chest, 11 spots within 13 cm, largest 2 cm in size).	Measurement of droplets only – no evidence on very small or airborne particles. **Does the study design control for potential confounders?** No: Authors do not report assessments pre-experiment to ensure any baseline droplets not associated with the procedure are accounted for. **Other concerns?** Most procedures only performed once.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
			Ultrasonic aspirator: No observable fluorescein droplets were noted in the measured surgical field in any direction for ultrasonic aspirator on the left sphenoid sinus, use of the ultrasonic aspirator on the right frontal sinus, and external activation of the ultrasonic aspirator.	
7	**Study:** Workman (2020a)[21] **Country:** USA **Aim:** "To assess nasopharyngeal suctioning as a mitigating approach to minimize, or potentially eliminate, airborne particulate spread during sinonasal surgery." **Design:** Cadaveric simulation using particle counter	**Procedure(s) performed:** *Procedure(s) evaluated:* - Drilling (with and without suction) - Electrocautery (with and without suction) *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated:* - suctioning *On:* Cadaver head (n=2) *By:* Not reported (n=not reported) *Where:* Laboratory *Procedure repetitions:* Each procedure performed in duplicate. **Outcomes measured:** *Measure:* - Aerosol number - Aerosol size - Aerosol concentration *Method:* Optical particle counter / sizer (OPS 3330; TSI Inc, Shoreview, MN).	**Key findings:** "The use of nasopharyngeal suctioning via the contralateral nostril minimizes airborne particulate spread during simulated sinonasal drilling and cautery." **Details:** *Drilling without suction:* Significant particulate generation in the 1-µm to 10-µm range during drilling of sphenoid rostrum ($p < 0.001$, $U = 56$, difference between medians = 120.5 particles/L) and anterior nasal septum/anterior medial maxillary wall ($p < 0.001$, $U = 26$, difference between medians = 403.6 particles/L, Mann-Whitney U test) *Drilling with suction:* With the suction turned on throughout the drilling period, significant 1-µm to 10-µm airborne particulate generation over baseline concentrations was not observed in either posterior or anterior drilling conditions. *Electrocautery without suction:* Significant airborne particulate generation in the 1-µm to 10-µm range was observed in the 60-second period following electrocautery ($p < 0.001$, $U = 0$, difference between medians = 120.5 particles/L), compared to matched-condition background levels.	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation, influence of breathing and nasal secretions not accounted for. **Are measurement tools appropriate / robust?** Unclear: Particle sizer. The methods are appropriate for 1 µm to 10 µm diameter size range. However, droplets (larger particles) are not measured as the authors point out. Especially close to the source larger particles could dry further and reduce in size. Figure 4 suggest particle numbers are non-zero at the upper size range. When scaled by volume of particles, the majority of the volume may be at higher sizes. **Does the study design control for potential confounders?** Yes: Prior to each simulation event, background sampling was obtained. Baseline airborne particulate concentrations were reached and measured prior to each new simulation. Suction

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
			Electrocautery without suction: With suction on, particulate generation in this range did not significantly differ from matched background levels during or following electrocautery.	used to evacuate any retained intranasal particulates following all drilling and cautery conditions. **Other concerns?** Limited data / repetitions. Difference between medians value for E*lectrocautery without suction* appears identical to value for *Drilling without suction* and may be a typographical error. The short time for electrocautery (1 min) relative to drilling (5 min) result in concentrations rising after the cessation of electrocautery.
8	**Study:** Workman (2020b)[22] **Country:** USA **Aim:** *"To (1) quantify airborne aerosol production following endonasal instrumentation."* **Design:** Cadaveric simulation using particle counter **Note:** *This study also provides findings on outpatient*	**Procedure(s) performed:** *Procedure(s) evaluated:* - Nasal suctioning - Non-powered instrument - Microdebrider - Drilling - Electrocautery *Patient behaviour(s) evaluated:* N/A *Device(s) evaluated:* N/A *On:* Cadaver head (n=2), *By:* Not reported (n=not reported) *Where:* Laboratory *Procedure repetitions:* Each intervention was performed in duplicate on 2 separate cadaver heads.	**Key finding:** *"Transnasal drill and cautery use is associated with significant airborne particulate matter production in the range of 1 to 10 µm under surgical conditions."* **Details:** *Nasal suctioning:* Did not produce significant detectable airborne aerosols in the range of 1 to 10 µm. *Non-powered instrument:* Did not produce significant detectable airborne aerosols in the range of 1 to 10 µm. *Microdebrider:* Did not produce 1- to 10-µm airborne aerosols over 10 sampling periods (5 minutes). *Drilling:* 3 separate drilling conditions were performed: Suction drill at 12,000 rpm; Diamond drill at 70,000 rpm; and Cutting drill at 70,000 rpm.	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation of surgery; no accounting for patient breathing / secretions. Volunteer-based clinical simulations do not account for patient characteristics – e.g. fever, increased secretions etc. **Are measurement tools appropriate / robust?** Unclear: Optical particle sizer able to measure particles from 1 to 10 µm. However, droplets (larger particles) are not measured as the authors point out. In addition, the lower detection limit of 1um may have precluded measurement of a large number of aerosols given that highest particles

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	nasendoscopy – see table 5 for details.	**Outcomes measured:** *Measure:* Aerosols *Method:* Optical particle counter / sizer (OPS 3330; TSI Inc).	In all 3 conditions, significant airborne aerosol generation in the range of 1 to 10 µm was observed. (P < .001 Mann-Whitney U test). *Electrocautery:* Transnasal electrocautery of the inferior turbinate demonstrated significant particle generation in the range of 1 to 10 µm over background in four 30-second samples (P < .001; Mann-Whitney U test).	counts by size (see figure 1c) are at the lowest end of the scale. **Does the study design control for potential confounders?** Yes: Baseline aerosols measured, between experiments allow for verification of return to baseline concentrations. Suction utilized to evacuate any retained intranasal particulates following drilling and electrocautery. The clinical examination room (111 sq ft) and the surgical laboratory (726 sq ft) were equipped with air exchangers operating at a rate of 6 total air changes per hour. **Other concerns?** The choice of units for the results (particle counts by size over a period of timed data rather than concentration) prevents comparison with other studies and a quantitative assessment of how much aerosol was generated or what the representative concentrations were.
9	**Study:** Workman (2020c)[23] **Country:** USA **Aim:** "To simulate nasal aerosolization	**Procedure(s) performed:** *Procedure(s) evaluated:* - Rigid nasendoscopy - Suctioning - Non-powered instrument - Microdebrider	**Key findings:** "Cold surgical [non-powered] instrumentation and microdebrider use pose significantly less aerosolization risk than a high-speed drill." **Details:**	**Is the study a reasonable representation of real-world clinical practice?** No: Cadaveric simulation of surgery; no accounting for patient breathing / secretions. Authors note that the atomizer used to simulate sneezes means

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	during a variety of endonasal procedures […] Outpatient sneezing during endoscopy was simulated […] in the presence or absence of intact and modified surgical mask barriers." **Design:** Cadaveric simulation using fluorescein **Note:** *This study also provides findings on outpatient nasendoscopy – see table 4 for details.*	- External activation of microdebrider - Drilling - External activation of drill *Patient behaviour(s) evaluated:* - N/A *Device(s) evaluated:* - N/A *On:* Cadaver head (n=1) *By:* Not reported (n=not reported) *Where:* Laboratory. *Procedure repetitions:* Not reported. **Outcomes measured:** *Measure:* Aerosols *Method:* Fluorescein solution (0.2 mg per 10 mL) and quantified using a blue-light filter and digital image processing. Images assessed using ImageJ software	*Nasal endoscopy:* No fluorescein-stained droplets were observed with a 0-degree endoscope. *Suctioning:* No fluorescein-stained droplets were observed from nasal suctioning with 8-French Frazier suction. *Non-powered instrument:* No fluorescein-stained droplets were observed from through-biting of the middle turbinate. *Microdebrider:* No fluorescein-stained droplets were observed from suction microdebrider applied to the posterior septum. *External activation of microdebrider:* No fluorescein-stained droplets were observed from external activation after tissue soilage. *Drilling:* High-speed drill at 70,000 rpm with a 5-mm cutting to remove bone at the sphenoid rostrum and nasal beak resulted in droplets observed in multiple distribution regions between 6 and 30 cm away from the nare. Maximum fluorescence intensity was significantly different in affected areas in the drilling conditions compared with baseline ($p < 0.01$, two-tailed t test). *External activation of drill:* External drilling had significantly more distribution regions affected than non-drill surgical conditions ($p < 0.05$, Fisher's exact test). *Simulated sneeze with mask devices:* Our data confirm that a simulated sneezing event can generate aerosols that settle maximally between 30 cm from the nare but can extend up to 66 cm.	that smaller particles of concern for airborne transmission were not formally assessed. There are few details on the atomisation and the provided reference does not provide relevant details. **Are measurement tools appropriate / robust?** Unclear: Unblinded review of presence or absence of fluorescent aerosolized droplet contamination verified by 2 separate authors. Authors note that it is possible that the microdebrider was capable of producing aerosols below estimated size detection limit of 20 µm. **Does the study design control for potential confounders?** Yes: Background fluorescence from a matched control condition was subtracted. **Other concerns?** Limited detail on methodology and appears that each procedure may have been performed only once.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
			Spread of these aerosols was effectively prevented by both the intact and VENT mask conditions.	

Table 4: Primary research on outpatient nasendoscopy (n=4 studies)

	Study details	Procedures and measures	Findings	Study contribution / limitations
1	**Study:** Murr (2020b)[18] **Country:** USA **Aim:** "*To provide a greater understanding of particle generation and exposure risk during endoscopic endonasal instrumentation"* **Design:** Clinical observation using particle counter.	**Procedure(s) performed:** *Procedures evaluated:* - Rigid endoscope - Non-powered instrumentation - Suction instrumentation *Patient behaviour(s) evaluated: N/A* *Device(s) evaluated: N/A* *On:* COVID-19 negative patients. (n=30) *By:* Usual clinician (surgeon) (n=not reported) *Where:* "Office-based" *Procedure repetitions:* 11 nasal endoscopies, 19 nasal endoscopies with debridement, 119 measurements. **Outcomes measured:** *Measure:* - Aerosol concentration *Method:*	**Key findings:** "Diagnostic nasal endoscopy with a rigid endoscope is not associated with increased particle aerosolization in patient for whom sinonasal debridement is not needed. In patients needing sinonasal debridement, endonasal cold [non-powered] and suction instrumentation were associated with increased particle aerosolization." **Details:** *Rigid endoscope [during diagnostic endoscopy]:* Mean particle concentration 6,021 p/ft3. Nonsignificant mean difference of −173 p/ft3 (95% CI −1,139 to 793; P = .698) compared to pre-procedure concentrations. *Non-powered instruments [during nasal endoscopy with debridement]:* Mean particle concentration 8,002 p/ft3. Significant mean increase of 2,462 p/ft (95% CI 837 to 4,088; P = .005) from pre-procedure levels. *Suction instrumentation [during nasal endoscopy with debridement]:* Mean particle concentration 8,514. Significant mean increase of 2,973 p/ft (95%	**Is the study a reasonable representation of real-world clinical practice?** Yes: real-world clinical observation involving live patients. **Are measurement tools appropriate / robust?** Unclear: Particle sizer calibrated to national standards. The sizer was not able to detect particles below 0.3um which was the size of most particles measured (72%). The instrument used has a 50% counting efficiency at these concentrations. **Does the study design control for potential confounders?** Unclear: Aerosol concentrations compared to pre-instrumentation levels. However, the setup was not shown schematically and sampling location with respect to ventilation can have an effect on particle concentrations in room. The study measures

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Optical particle counter (Extech VPC300).	CI from 1,419 to 4,529; P = .001) compared pre-procedure levels. *Rigid endoscope [during nasal endoscopy with debridement]:* Mean particle concentration 7,169 p/ft3. Nonsignificant but trended mean increase of 1,629 p/ft3 (95% CI −96 to 3,354; P = .063) from pre-procedure levels.	concentrations in the room rather than at the source.
2	**Study:** Tan (2020)[30] **Country:** Singapore **Aim:** *"To assess respiratory droplet generation and dispersal during nasendoscopy and swab testing."* **Design:** Simulation in healthy volunteers using video recording	**Procedure(s) performed:** *Procedure(s) evaluated:* - Nasendoscope (with and without cophenylcaine spray decongestion) *Patient behaviour(s) evaluated:* - Sneezing - Coughing - Speech - Swallowing - Tongue protrusion Device(s) evaluated: *N/A* *On:* Volunteers (n=3) *By:* Not reported (n=not reported) *Where:* Laboratory *Procedure repetitions:* Unclear **Outcomes measured:** *Measure:* Droplets *Method:* Digital camera at 60 frames per second. Illumination provided through a	**Key findings:** "Our study demonstrates that droplets clearly form under three scenarios during nasendoscopy." **Details:** *Nasendoscope:* Video analysis reveals droplet formation in three manoeuvres during nasendoscopy - sneezing, vocalization, and nasal decongestion spray. A capillary bridge of mucus can be seen when a nasendoscope exits wet nares.	**Is the study a reasonable representation of real-world clinical practice?** Unclear: Performed with 'healthy volunteers', unclear how aerosol production might be affected in patients with a viral infection. **Are measurement tools appropriate / robust?** No: Authors note that A technical limitation of our study is that our equipment can only adequately assess droplet formation. Aerosols below 10 µm (10 µm) are unlikely captured in the images. **Does the study design control for potential confounders?** Unclear: No information provided on accounting for background / baseline levels. **Other concerns?** Limited detail provided about this study. Findings not reported for cough, tongue protrusion and swallowing.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		green laser light. Relevant frames combined into one image.		Aerosols labelled in one figure appear to come directly from the nasal spray rather than the patient. Unclear whether nasendoscopy was rigid or flexible.
3	**Study:** Workman (2020b)[22] **Country:** USA **Aim:** *"To (1) quantify airborne aerosol production following endonasal instrumentation and (2) determine the relative efficacy of source control solutions."* **Design: H**ealthy volunteer simulation using particle counter **Note:** *This study also provides findings on endoscopic sinus surgery – see table 4 for details.*	**Procedure(s) performed:** *Procedure(s) evaluated:* - Rigid nasendoscopy - Topical spray (1% lidocaine and oxymetazoline 0.05% solution) *Patient behaviour(s) evaluated:* - Coughing - Sneezing - Heavy breathing - Speech *Device(s) evaluated:* Simulated sneezing evaluated with patient use of - Standard level 1 surgical mask - N95 surgical mask - modified N95 VENT respirator (valved endoscopy of nose/throat) - Removal of N95 mask 30 seconds after sneeze – to evaluate aerosol release *On:* healthy volunteers (n=2) *By:* Not reported (n=not reported)	**Key finding:** *"During simulated clinical activity, airborne aerosol generation was seen during nasal endoscopy, speech, and sneezing. Intact or VENT-modified N95 respirators mitigated airborne aerosol transmission, standard surgical masks did not."* **Details:** *Nasal endoscopy:* Nasal endoscopy generated significant airborne aerosols (P < .05, U = 10, n = 8; Mann-Whitney U test). *Topical spray:* Airborne aerosols comparable to those generated with sneezing (P<.01, U = 0, n = 4; Mann-Whitney U test). *Patient behaviours:* Panting and coughing generated detectable 1- to 10- µm aerosols that were not significantly greater than background. Speech generated significant airborne aerosols (P < .01, U = 6.5, n = 10; Mann-Whitney U test). Simulated sneezing generated the most airborne particles per minute by an order of magnitude (P < .01, U = 0, n =4; Mann-Whitney U test). *Simulated Sneeze Under Masked Conditions:* Surgical mask alone attenuated airborne aerosol generation; however, statistically significant aerosol escape was still detected (P<.05, U = 2, n =	**Is the study a reasonable representation of real-world clinical practice?** No: Volunteer-based clinical simulations do not account for patient characteristics – e.g. fever, increased secretions etc. **Are measurement tools appropriate / robust?** Yes: Optical particle sizer used and measures particles in range of 1- to 10- µm. **Does the study design control for potential confounders?** Yes: Baseline aerosols measured, between experiments allow for verification of return to baseline concentrations. The clinical examination room (111 sq ft) and the surgical laboratory (726 sq ft) were equipped with air exchangers operating at a rate of 6 total air changes per hour. **Other concerns?** The choice of units for the results (particle counts by size over a period of timed data rather than concentration) prevents comparison with other

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		Where: In a 'clinical examination room' *Procedure repetitions:* Each intervention was performed in duplicate on 2 participants. **Outcomes measured:** *Measure:* Aerosols *Method:* Optical particle counter / sizer (OPS 3330; TSI Inc).	4; Mann-Whitney U test). N95 respirator and modified N95 VENT respirator ameliorated airborne particle generation to background levels. N95 doffing following simulated sneezing did not reach significance above background.	studies and a quantitative assessment of how much aerosol was generated or what the representative concentrations were. Although the text says that airborne aerosols from *Topical spray* are comparable to those generated with sneezing, Fig 2C suggests this is higher than sneezing with no mask by an order of magnitude.
4	**Study:** Workman (2020c)[23] **Country:** USA **Aim:** "To simulate nasal aerosolization during a variety of endonasal procedures […] Outpatient sneezing during endoscopy was simulated […] in the presence or absence of intact and modified surgical mask barriers."	**Procedure(s) performed:** *Procedure(s) evaluated:* - Rigid nasendoscopy *Patient behaviour(s) evaluated:* - Sneezing (with and without masks) *Device(s) evaluated:* - Surgical mask - surgical mask with perforation to allow the passage of an endoscope; - modified valved endoscopy of the nose and throat (VENT) mask *On:* Cadaver head (n=1) *By:* Not reported (n=not reported) *Where:* Laboratory.	**Key findings:** "Among outpatient conditions, a simulated sneeze event generated maximal aerosol distribution at 30 cm, extending to 66 cm. Both an intact surgical mask and a modified VENT mask eliminated all detectable aerosol spread." **Details:** *Nasal endoscopy:* No fluorescein-stained droplets were observed with a 0-degree endoscope. *Simulated sneeze:* Our data confirm that a simulated sneezing event can generate aerosols that settle maximally between 30 cm from the nare but can extend up to 66 cm. *Simulated sneeze with mask devices:* Spread of these aerosols was effectively prevented by both the intact and VENT mask conditions.	**Is the study a reasonable representation of real-world clinical practice?** No: There are few details on the atomisation (simulated sneeze) such that it is difficult to determine the representativeness of the findings. However, the authors note that because the atomizer produces sprays between 30 and 100 µm smaller particles of concern for airborne transmission were not formally assessed. **Are measurement tools appropriate / robust?** Unclear: Unblinded review of presence or absence of fluorescent aerosolized droplet contamination verified by 2 separate authors. There is no reference made to previous studies using the same approach. The

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	Design: Cadaveric simulation using fluorescein **Note:** *This study also provides findings on endoscopic sinus surgery – see table 4 for details.*	*Procedure repetitions:* Not reported. **Outcomes measured:** *Measure:* Aerosols *Method:* Fluorescein solution (0.2 mg per 10 mL) and quantified using a blue-light filter and digital image processing. Images assessed using ImageJ software		measured droplet size appears to be the size of the droplet when deposited on the surface and there doesn't appear to be a correction for size when airborne. **Does the study design control for potential confounders?** Yes: Background fluorescence from a matched control condition was subtracted. **Other concerns?** Limited detail on methodology and appears that each procedure may have been performed only once.

Tables 1 to 6: Evidence tables for included studies

Table 5: Primary research on suction for airway clearance* (n=6 studies)

	Study details	Procedures and measures	Findings	Study contribution / limitations
1	**Study:** Chan (2018)[24] **Country:** Hong Kong **Aim:** *"To estimate the spread of exhaled air during episodes of coughing bouts triggered by oro-tracheal suctioning."* **Design:** Simulation using human-patient simulator and smoke	**Procedure(s) performed:** *Procedure(s) evaluated:* - bag-mask ventilation - episodes of coughing bouts triggered by orotracheal suctioning *Patient behaviour(s) evaluated:* - Coughing Device(s) evaluated: *N/A* *On:* Human patient simulator with and without intubation (n=N/A) *By:* Usual clinician (various HCW) and medical students (n=20) *Where:* Not reported. *Procedure repetitions:* Unclear. **Outcomes measured:** *Measure:* Droplet spread. *Method:* Smoke particles of <1 µm in diameter, produced by a M-6000 smoke generator were illuminated by a green (532 nm wavelength) laser light-sheet. Images were captured by high-definition camera.	**Key finding:** "Coughing during oro-tracheal suctioning could produce substantial dispersion of potentially infected exhaled air. Nevertheless, suctioning reduced the spread of exhaled air during coughing bouts by >32% whereas continuous suctioning could reduce exhaled air distances more effectively than intermittent suctioning." **Details:** *Coughing*: Exhaled air dispersion decreased with worsening coughing efforts. Before tracheal intubation, exhaled air leaked through the mouth to a distance of 860 ± 93 mm during normal cough. This was reduced to 298 ± 43 mm in mild coughing effort and 185 ± 19 mm with poor coughing effort, $p < 0.001$. Following tracheal intubation, the dispersion distance of exhaled air after a normal cough was 460 ± 127 mm. This was decreased to a distance of 305 ± 77 mm in mild coughing effort and 188 ± 63 mm in poor coughing effort, $p < 0.001$ *Suctioning*: In cases without tracheal intubation, continuous suctioning reduced spread better than intermittent suctioning, adjusted for coughing efforts, $p < 0.001$. On average, suctioning decreased exhaled air dispersion by >32% (range: 8.2–73.0%.	**Is the study a reasonable representation of real-world clinical practice?** No: Laboratory-based simulation. Influence of live patient factors such as breathing and nasal secretions not accounted for. **Are measurement tools appropriate / robust?** Unclear: Unclear how appropriate smoke is as a proxy for aerosols. **Does the study design control for potential confounders?** Yes: Subtracted the background intensity with images taken with the laser turned off. **Other concerns?** Unclear how many procedure repetitions there are.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
2	**Study:** Heinzerling (2020)[25] **Country:** USA **Aim:** *"To better characterize and compare exposures among 121 HCP who did and did not develop COVID-19 following exposure to a patient."* **Design:** Retrospective cohort study	**Procedure(s) performed:** *Procedure(s) evaluated:* - Airway suctioning *Patient behaviour(s) evaluated: N/A* Device(s) evaluated: *N/A* *On:* SARS-Cov-2 patient (n=1) *By:* Usual clinician (various HCW) (n=7) *Where:* Not reported. *Procedure repetitions:* Not reported. **Outcomes measured:** *Measure:* Transmission. *Method:* Nasopharyngeal and oropharyngeal specimen testing.	**Key finding:** Airway suctioning was performed by seven HCW exposed to an infected patient; none developed SARS-Cov-2 infection. **Details:** *Suctioning:* Airway suctioning was not performed by any of the 3 HCW with SARS-CoV-2 infection, and was performed by 7 (21%) of the 34 HCW who were exposed but not infected. No-one wore PPE as transmission based precautions not applied	**Is the study a reasonable representation of real-world clinical practice?** Yes: Clinic-based evaluation. **Are measurement tools appropriate / robust?** No: Risk of recall bias; procedure data are collected via interview and depend on how accurately HCW can recall what they did. **Does the study design control for potential confounders?** No: HCW performed multiple procedures so unclear which (if any) are responsible for infections. HCW may have been infected by another source. Only HCW who were symptomatic were tested for SARS-Cov-2; and only those tested were interviewed. There were many more HCW who had contact and deemed to be at high or medium risk of exposure (n=94). So there may have been HCW who were infected but asymptomatic and so would not have been tested. **Other concerns?** Very little data on suctioning. Data based on n=3 diagnoses of COVID among exposed staff. No measure of duration of exposure
3	**Study:** Loeb (2004)[26] **Country:** Canada **Aim:** *"To determine risk factors for SARS among nurses who worked in*	**Procedure(s) performed:** *Procedure(s) evaluated:* - Suctioning before intubation - Suctioning after intubation	**Key finding:** "We found that critical care nurses who assisted with suctioning before intubation and intubation of SARS patients were four times more likely to become infected than nurses who did not."	**Is the study a reasonable representation of real-world clinical practice?** Yes: clinic-based evaluation. **Are measurement tools appropriate / robust?** No: Risk of recall bias; procedure data are collected via interview and

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	two critical care units in a Toronto hospital." **Design:** Retrospective cohort study	*Patient behaviour(s) evaluated: N/A* Device(s) evaluated: *N/A* *On:* SARS patients (n=3) *By:* Usual clinician (Nurses) (n=32) *Where:* Hospital ward / room *Procedure repetitions:* n=4 before intubation, n=19 after intubation **Outcome measures:** *Measure:* Virus transmission *Method:* Confirmed by antibody test.	**Details:** *Suctioning before intubation:* 75% of nurses who performed suctioning before intubation were infected with SARS (3/4 nurses) compared to 18% of nurses who did not perform suction prior to intubation (5/28 nurses). Relative risk 4.20; CI 95% 1.58 to 11.14; P value 0.04. *Suctioning after intubation:* 21% of nurses who performed suctioning after intubation were infected with SARS (4/19 nurses) compared to 31% of nurses who did not perform suction prior to intubation (4/13 nurses). Relative risk 0.68; CI 95% 0.21 to 2.26; P value 0.68. Note: The authors report that all 3 nurses involved in suctioning before intubation who acquired SARS one reported consistent PPE use including N95 mask and two reported inconsistent PPE use.	depend on how accurately nurses can recall what they did. **Does the study design control for potential confounders?** No: Nurses performed multiple procedures so unclear which (if any) are responsible for infections. No comparison of how much time nurses spend patient's room. Nurses may have been infected by another source. **Other concerns?** Small sample size.
4	**Study:** Raboud (2010)[27] **Country:** Canada **Aim:** *"To identify risk factors associated with transmission of SARS-CoV from patients requiring intubation to HCWs involved in their care."*	**Procedure(s) performed:** *Procedure(s) evaluated:* - Suctioning before intubation - Suctioning after intubation *Patient behaviour(s) evaluated: N/A* Device(s) evaluated: *N/A* *On:* SARS patients (n=45)	**Key finding:** No evidence of association of suction for airway clearance with SARS infection. **Details:** *Suctioning before intubation:* Suctioning before intubation was undertaken by 27% of nurses infected with SARS (7/26 nurses) compared to 18% of uninfected nurses (106/598 nurses). Fishers exact test p value = 0.29.	**Is the study a reasonable representation of real-world clinical practice?** Yes: clinic-based evaluation. **Are measurement tools appropriate / robust?** No: Risk of recall bias. Procedure data from HCW recall – interviews conducted up to 10 months post-procedure. **Does the study design control for potential confounders?** No: HCW didn't necessary

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	Design: Retrospective cohort study	*By:* Usual clinician (various HCW) (n=624) *Where:* Hospital ward / room *Procedure repetitions:* n=17 **Outcome measures:** *Measure:* Virus transmission *Method:* Confirmed by antibody test or met case definition.	*Suctioning after intubation:* Suctioning after intubation was undertaken by 38% of nurses infected with SARS (10/26 nurses) compared to 26% of uninfected nurses (155/598 nurses). P value = 0.16. In the multivariate logistic regression model (to account for correlation among responses from HCWs caring for the same patient) suctioning was not found to be an independent predictor of SARS infection. Note: HCWs who contracted SARS were "more likely to have used less effective methods of respiratory protection while in a patient's room (p= .04)". There is no specific information about mask use during suctioning.	perform procedure – they were considered 'exposed' if they reported being in room while the patient received the procedure. HCW perform multiple procedures so unclear which (if any) are responsible for infection. No information on duration of procedures, use of PPI in relation to specific procedures, length of time spent in patients' room. HCW may have been infected by another source **Other concerns?** Limited evidence about suctioning.
5	**Study:** Thompson (2013)[28] **Country:** UK **Aim:** *"To: 1) Establish if World Health Organization defined 'aerosol generating procedures' produce infectious aerosols. 2) If detectable clouds are produced then determine infectious aerosol concentration and particle size. 3) To use this information to*	**Procedure(s) performed:** *Procedure(s) evaluated:* - Respiratory & Airway Suction (performed during an aerosol generating procedure and compared to baseline period) *Patient behaviour(s) evaluated: N/A* Device(s) evaluated: *N/A* *On:* H1N1 patients (n=11) *By:* Usual clinician (not specified) (n=not reported) *Where:* Hospital ward / room	**Key findings:** Respiratory/airway suctioning "appears to be related to an increased likelihood of viral aerosol generation." Results indicate that respiratory and airway suction "tends to produce aerosols of smaller particle sizes than baseline levels" but the difference was not statistically significant **Details:** *Particle size:* Compared to baseline samples the RNA recovered during respiratory and airway suctioning were smaller. In baseline the majority of RNA (78.7%) were found in particles larger than 7.3 µm. In suctioning	**Is the study a reasonable representation of real-world clinical practice?** Yes: clinic-based evaluation. **Are measurement tools appropriate / robust?** Unclear: Authors report that May impinger does not collect particles <,0.86 µm aerodynamic particle size, several studies have reported finding influenza RNA in air particles <,1 µm, thus it is possible that some of the aerosolized RNA was missed. **Does the study design control for potential confounders?** Yes: Baseline samples taken when no activity that could be defined as an AGP was taking place. Staff respirators /

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
	inform infection control practice." **Design:** Clinical observation with particle counter	*Procedure repetitions:* n=14 **Outcome measures:** *Measure:* - Viral RNA aerosol concentration - Particle size *Method:* Particle counter / sizer (Glass May 3-stage impingers produced at HPA, Porton Down). PCR used to detect the presence of any influenza A RNA.	the majority of RNA (77.6%) were found in particles smaller than 7.3 µm. *Aerosol generation:* An increased probability associated with airway suctioning but not statistically significant (OR = 4.11 (0.50–34.0)).	vaccinations mean that it is "unlikely that the influenza aerosols could have been generated by anyone other than the patient on whom the AGP was being performed.
6	**Study:** Weber (2019)[29] **Country:** USA **Aim:** *"To characterize the magnitude of environmental contamination—in air, on surfaces and on participants—associated with seven common healthcare activities."* **Design:** Laboratory simulation using 'task trainers' and fluorescein	**Procedure(s) performed:** *Procedure(s) evaluated:* - Suctioning to remove secretions *Patient behaviour(s) evaluated:* - Coughing - Vomiting Device(s) evaluated: *N/A* *On:* 'task trainers' (mannequins) (N/A) *By:* Usual clinician (various HCW) (n=39) *Where:* Laboratory *Procedure repetitions:* n=180 **Outcome measures:** *Measure:* - Droplets	**Key finding:** "In this study, we did not observe AGPs [including suctioning] to be associated with increased frequency of fluorescein in air relative to other activities." **Details:** *Droplets:* Fluorescein was detected at lower levels on face shields and facemasks for suction than for other activities (bathing, central venous access, intravenous access, physical examination and vital signs assessment). Median fluorescein concentration in air from 10 tests at 1m (25^{th}, 75^{th} percentile) 3.93ng m^{-3} (2.41, 6.39); not detected in 30%. In 9 tests in personal breathing space, median concentration 3.16 ng m^{-3} (1.07, 9.26), 75% not detected	**Is the study a reasonable representation of real-world clinical practice?** No: Laboratory simulation with 'task-trainers'. Some efforts to replicate real life scenarios however; researcher squeezed lungs to simulate cough/vomit and participants were allowed to perform the healthcare activities as normal, rather than following a detailed study protocol. **Are measurement tools appropriate / robust?** Unclear: Aerosols measured by calibrated fluorometer but no information on who or how many people visually assessed droplets or what approach was used to ensure completeness of data. No information provided about the size of particles detectable or the efficiency as a function of particle size of the Biosampler liquid impinger or personal filters.

Tables 1 to 6: Evidence tables for included studies

	Study details	Procedures and measures	Findings	Study contribution / limitations
		- Aerosols *Method:* Aerosols measured via Fluorescein concentration using a Trilogy benchtop fluorometer. Fluorescein droplets on the HCW's body were visually assessed using black lights. Measurements taken at stationary point 1m from procedure and within the personal breathing space	No fluorescein was detected on face or face shield and there was no association between concentration on face shield and in air (Spearman's ρ = 0.09, *P* = 0.49) *Aerosols:* The difference in proportion of samples positive for fluorescein were not statistically significantly between healthcare activities.	**Does the study design control for potential confounders?** Yes: Blank samples (negative controls) of aerosol sampling devices were used to correct measured values and sample extraction efficiency. For droplets measures are obtained (i) prior to the start of the healthcare activity (as a baseline), (ii) directly after the healthcare activity and (iii) after doffing PPE. **Other concerns?** It is difficult to justify comparing the different tasks quantitatively (amount of fluorescein in samples) because of the starting conditions. For example, for intubation 300ml of liquid has been 'poured through mouth to lungs and stomach' compared to 100 ml poured onto two areas of the body for bathing. In the latter case all of the fluorescein will be external, while in the former it may be only a small amount that comes into contact with the endoscope.

*Evidence on suction for reduction of aerosol dispersal can be found in table 3 on nasendoscopy and nasal electrocautery

Tables 1 to 6: Evidence tables for included studies

Table 6: Systematic reviews with evidence on research and guidance (n=4)

	Review details	Findings	Evidence limitations / overlap
1	**Review:** Thamboo (2020)[34] Clinical evidence based review and recommendations of aerosol generating medical procedures in otolaryngology–head and neck surgery during the COVID-19 pandemic. J. Otolaryngology-head and neck surgery, 2020; 49: 28-42 **Aim:** *"To identify potential AGMPs in Otolaryngology - Head and Neck Surgery and provide evidence-based recommendations."* **Inclusion criteria:** *"English articles, clinical or experimental studies involving procedures in the head and neck region."* **Focus on which procedures?:** *Nasogastric tube insertion:* No *Lung function tests:* No *Dysphagia assessments:* No *Nasoendoscopy / nasal cautery:* Yes *Suction for airway clearance:* No	**Research evidence:** **Nasoendoscopy / nasal cautery:** - **Nasoendoscopy:** (n=1 study) *"Only one study [Workman 2020c] evaluating the aerosolization risk during nasal endoscopy was identified." (See Workman 2020c in Table 3)* - **Endoscopic Sinonasal surgery:** (n=1 study) *"Workman et al. (2020c) investigated the aerosolization risk during endoscopic sinonasal procedures" (See Workman 2020c in Table 3)* - **Electrocautery:** (n=6 studies) "Four, direct crosssectional studies, two experimental studies […]There is consistent, direct evidence indicating that electrocautery can result in small aerosols with potential spread over longer distances. It is uncertain if this can actually lead to clinically relevant transmission of viable pathogens." **Available guidance:** N/A guidance not included	**Limitations:** - *Very limited evidence re nasoendoscopy / endoscopic surgery.* - *Cautery evidence unclear if nasal cautery / non-COVID patients.* **Overlap:** • Nasal Endoscopy (n=1 study - Workman (2020c)) • Endoscopic Sinonasal and Anterior Skull Base Surgery (n=1 study – Workman (2020c)) • Electrocautery (n=6 studies) (none in current review)

Tables 1 to 6: Evidence tables for included studies

2.	**Review:** Tran (2012)[33] Aerosol Generating Procedures and Risk of Transmission of Acute Respiratory Infections to Healthcare Workers: A Systematic Review. PLoS ONE, 2012; 7(4): e35797 **Aim:** *"To determine the clinical evidence for the risk of transmission of ARIs [acute respiratory infections] to HCWs caring for patients undergoing AGPs compared with the risk of transmission to HCWs caring for patients not undergoing AGPs."* **Inclusion criteria:** *Design: health technology assessments (HTAs), systematic reviews, meta-analyses, randomized controlled trials, and non-randomized studies. Population: HCWs caring for patients with acute respiratory infections. Intervention: provision of care to patients undergoing aerosol generating procedures. Comparator: provision of care to patients not undergoing aerosol generating procedures. Outcome: risk of transmission of acute respiratory infections from patients to HCWs.* **Focus on which procedures?:** *Nasogastric tube insertion:* Yes *Lung function tests:* No	**Research evidence:** **Nasogastric tube insertion:** *"Pooled estimates suggest that […] insertion of nasogastric tube […] might be associated with an increased risk of transmission, but the odds ratios were not statistically significant."* *- Nasogastric tube insertion (2 cohort studies) Pooled Estimate: Odds Ratio: 1.2; 95% CI: 0.4- 4.0; I squared: 0%.* **Suctioning for airway clearance:** *"Pooled estimates suggest that […]suction before intubation [and] suction after intubation […] might be associated with an increased risk of transmission, but the odds ratios were not statistically significant."* *- Suction before intubation (2 cohort studies) Pooled Estimate: Odds Ratio: 3.5; 95% CI: 0.5-24.6; I squared: 59.2%.* *- Suction after intubation (2 cohort studies) Pooled Estimate: Odds Ratio: 1.3; 95% CI: 0.5-3.4; I squared: 28.8%.* **Available guidance:** N/A guidance not included	**Limitations:** - *Limited evidence for each outcome.* - *Non-COVID-19 patients.* **Overlap:** The 2 studies for all outcomes are Raboud (2010) and Loeb (2004). See tables 1 and 5 for details.

Tables 1 to 6: Evidence tables for included studies

	Review details	Findings	Evidence limitations / overlap
	Dysphagia assessments: No *Nasoendoscopy / nasal cautery:* No *Suction for airway clearance:* Yes