Guidelines for potential aerosol-generating procedures (AGPs) within the ENT clinic: Version 3

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Introduction

To create an advisory document that provides clear definitive advice for ENT surgeons carrying out upper airway endoscopy is extremely challenging. We are all dealing with a highly dynamic situation, in which it is difficult to be prescriptive. However, we can aim to offer some sensible advice that can be applied to local circumstances and personal choice.

Objectives of these guidelines

This revision provides considered recommendations in the light of the current situation. The prime aim is to maintain safe standards to minimise the risk to patients, healthcare staff and students.

Since the last guidance revision there have been several key changes:

1. The pandemic persists but the UK prevalence has declined.
2. The UK covid rates are moderately high and stable, but recently complicated by the introduction of the new Omicron variant
3. The vaccination rate is good and progressing
4. We have a greater understanding of the aerosol generating potential of upper airway diagnostic outpatient endoscopy

We acknowledge the essential diagnostic importance of upper airway endoscopy in ENT patients, and that it is not an option to avoid endoscopy. We are also aware that a balance must be struck with clinical throughput as well as training opportunities.

Vaccination rates are good, but it is clearly apparent that covid is still prevalent. Covid still occurs in vaccinated individuals, and whilst it reduces the likelihood of serious disease, disabling symptoms from long covid can still occur. However, the new variant is currently an unknown quantity, and as the effectiveness of vaccination against this variant is currently unknown.
The most important factors to consider when considering risk are the:

1. incidence of covid in the local community,
2. ventilation characteristics of the clinical environment,
3. risk of endoscopy-induced aerosol generation
4. use of appropriate PPE

Incidence of covid in the local community,

We know that Infection with SARS-CoV-2 virus requires exposure to a significant viral load. Whilst most patients will be aware of symptoms, some viral-positive patients may not develop viral symptoms or may be asymptomatic during the days before becoming viral. This poses a significant risk to healthcare professionals.

Ventilation characteristics of the clinical environment

WHO recognises that Covid is mainly transmitted by airborne aerosolised virus particles. Air quality and ventilation within outpatient clinical settings is therefore of utmost importance and is essential to facilitate safe endoscopy.

Risk of endoscopy-induced aerosol generation.

Most upper airway endoscopies will not generate an aerosol. However, should the patient sneeze or have a coughing fit, an aerosol is likely to be generated. This latter risk is important as this could spread infection and affect staff safety, as well as the next patient in the room, should the patient be viral positive.

The above factors have been considered in drawing up these guidelines. The need for a separate well ventilated endoscopy procedure room has also been reviewed in the light of impaired patient flow, and training opportunities.

1 The current state of Covid-19 in the UK

Covid-19 has now been prominent in the UK since March 2020. The virus, the disease and the risks are now much better understood. Vaccination is progressing well:
Currently, initial vaccination is at 76%; full vaccination is 69%; 28% have received a booster dose.

The D-variant still predominates, is likely to persist and can spread easily and rapidly. However, a new variant from South Africa, known as Omicron, poses a new danger of which we so far have little knowledge.

The numbers with Covid within the community are moderate, but stable, in contrast to the recent large rises seen in Austria and the Netherlands.

Covid is unpredictable, potentially lethal, and affects all age groups, but the older age groups are more vulnerable if infected.

The potential risk of contracting Covid-19 infection in the ENT clinic remains, and whilst the risk may remain relatively low, it is not negligible.

The relaxation of the rules, with decreased precautions has contributed to the change in peoples’ perception of the virus. There is now a real risk of complacency across society, both in public and professional domains.

2 Spread of SARS-Cov-2 infection

The concepts of viral load, room ventilation and viral spread via an aerosol (airborne) transmission route are much more appreciated. Whilst the potential of spread remains significant, in reality, very little spread from patient to medical/nursing staff has been identified.

3 Upper airway endoscopy and risk of Covid-19
Upper airway endoscopy is still considered as a potential aerosol-generating procedure AGP, and whilst an AGP is unlikely, this still can occur and is unpredictable. The principles of safety described within this document apply to both flexible and rigid endoscopy of the nose, nasopharynx, pharynx, and larynx.

4 How to maintain safe endoscopy

The degree of risk for a viral positive patient during upper airway diagnostic endoscopy in clinic is low, but the potential still exists, and the consequences can be serious.

The following guidance aims to minimise this risk:

4.1 The endoscopy procedure

Pre-endoscopy directions: patients should be asked to avoid sneezing and coughing. Patients should also be asked to give some degree of warning of an impending sneeze to allow the clinician to back away.

Face masks: patients should keep their face masks on during the endoscopic procedure. The mask should cover at least the mouth and will help to contain any aerosol in the event of coughing or sneezing being induced.

If increased risk is perceived, the mask should also cover the nose to offer better protection. The endoscope is then passed through a cut in the mask.

Video monitoring: An endoscopic camera and monitor is essential for allow for a safe distance between the clinician and the patient. Compromising this arrangement by asking the clinician to utilise the endoscopic eyepiece could place clinicians at much greater risk.
4.2 PPE

**Recommended PPE:** Full PPE includes an FFP3 facemask, visor, gown, and gloves.

However, this is an area where it is difficult to be prescriptive and will be dependent on local factors such as the ventilation characteristics and local numbers of Covid infections.

Full PPE protection is probably unnecessary for every case, but an FFP3 mask, with a plastic apron and gloves is still a sensible option.

However, this should remain as a personal option, as further waves of Covid may increase the degree of risk.

It would be wise for support staff to wear at least basic PPE during the procedure.

4.3 The room setting

Diagnostic endoscopy can be performed in either:

a) a clinic room used for the consultation or

b) a separate endoscopy room, according to local circumstances.

The clinic room may be more convenient, but should a potential AGP event occur, the room should remain fallow (please see para 4.4), thus disrupting clinical activity.

The ideal situation is a separate endoscopy room that is also fully ventilated. However, not all clinical rooms are fully ventilated as the focus for many years has been on heat retention rather than air quality. More than one room may be required, according to the number of consultation rooms that are in use.
A separate endoscopy room provides a much safer environment and should not interrupt clinical activity if an untoward event occurred. However, it does prevent the room being used as a consulting room.

The latter comes down to personal choice and local circumstances. A good compromise is to maintain one endoscopy room and most importantly, to give clinicians the choice as to where they prefer to perform endoscopy so that their personal safety, and that of their patients, is not compromised.

With aerosol spread being the most important vector for viral transmission, room ventilation is of utmost importance. However, this is a highly contentious point as many NHS clinic rooms have inadequate and insufficient ventilation and airflow. Keeping windows open has the practical consequence of having cold rooms and does not give full ventilation to all the room (please see Appendices). Keeping doors open does not permit adequate patient confidentiality and may also allow venting of an infected aerosol into the corridor or waiting room.

4.4 How to manage a potential AGP incident
If an AGP incident did occur during endoscopy, then the room air/possible infected aerosol needs time to clear. The clearance of air within a room is governed by the principles of ventilation documented in the appendices below and will depend upon the room’s ventilation characteristics. With regard to the timeframe needed to clear the room of aerosol, this will vary according to the room used for endoscopy, and local advice should be sought. However, such events will be infrequent.

4.5 Medical student teaching and support staff during endoscopy
An attending nurse should always be present during an endoscopic procedure, to act as a chaperone and, most importantly, for patient safety should a vasovagal episode be induced.
Should an AGP incident occur, staff and students should ideally leave the room if they are not wearing an FFP3 mask.

4.6 Additional safety measure in the event of another SARS-Cov-2 wave

Should numbers of Covid episodes start to increase again within local communities, performing a Lateral Flow Test on the patient prior to endoscopy may help protect health care staff during endoscopic assessment of the upper respiratory tract. The sensitivity is 77% when performed by a health care professional and rises to 95% should there be a high viral load.

Key principles and revised recommendations

1 Key principles

1.1 A designated, suitably ventilated, endoscopy room should be available within the outpatient clinic suite.

1.2 It is acknowledged that few upper airway endoscopies will generate an aerosol. If an aerosol is generated, this will be clearly recognised by the endoscopist at the time.

1.3 A facemask worn by the patient will help to contain an aerosol should this be induced during endoscopy.

1.4 All clinical personnel in the vicinity will need to wear appropriate PPE.

1.5 PPE items may include a facemask, visor, gown, plastic apron and gloves. The priority is to protect against inhalation of an infective aerosol.

Essential

- FFP3 mask – recommended as the best antiviral protection.
- Surgical face mask – offers some protection (improved with the addition of a visor).
- Disposable gloves.
Recommended but not mandatory

- Gown – ideal option for endoscopist.
- Plastic apron - should prevent potential contamination of clinician’s clothes.

2 Revised recommendations

2.1 An endoscopy room

- Clinical rooms where endoscopy is to be performed should, at the very least, be well ventilated.

- Ideally, a designated endoscopy room with mechanical negative ventilation and a known rate of air changes per hour (ACH) should be available.

- If the clinician is happy to proceed with endoscopy in the clinic room, this may be acceptable with low-risk patients and adequate ventilation. However, there is a risk element that needs to be carefully evaluated and considered should an aerosol incident occur.

2.2 The patient

- The patient should wear a surgical mask covering his or her mouth and ideally nose during the procedure.

- Patients should be asked to avoid sneezing or coughing during the procedure. They should be asked to provide a non-verbal warning should a sneeze or cough be impossible to suppress.

2.3 The endoscopic procedure

- The surgeon should wear suitable PPE as described in section 1.5.
• The ENT surgeon should be fully supported by nursing/ancillary staff during the procedure.

2.4 **Action to be taken in the event of a potential aerosol generation**

• Should the patient cough or sneeze during the procedure whilst wearing a surgical mask, any aerosol generated should be relatively contained.

• Should a potential aerosol be generated by the patient, the staff and students should leave the room immediately.

• The ENT surgeon may need to leave the room if PPE is deemed non-protective.

• The patient should vacate the room after the procedure.

• The room should be left empty and fallow for a period of time, based upon local microbiological advice and clinician input. The exact mechanism of allowing clearance of the aerosol produced will depend on the room ventilation characteristics (e.g. mechanical air extraction, or natural ventilation).

2.5 **After the procedure**

• The surfaces should be cleaned after each procedure.

• The room should be thoroughly cleaned at the end of the session according to local Trust IPC guidance.

• There is no need to have a fallow period if no AGP has been produced.

**Summary**

i). The current risk of being exposed to a patient infected with SARS-Cov-2 is variable and currently moderate.
ii). The risk of upper airway endoscopy inducing an aerosol is low.

iii). The combined relative risk makes exposure to the virus relatively low, but the risk is still present. This needs to be balanced with the fact that the relationship between the new Omicron variant and vaccination is unknown.

iv). We have a duty to ensure the optimum safety of patients, clinical personnel, students, and ourselves.

v). The most important objective is to prevent inhalation of infective air should an aerosol be generated.

vi). Whilst a facemask is essential, an FFP3 mask offers the best protection.

vii). The clinical room should be adequately ventilated. Should an aerosol be generated, a room rest period is recommended. The duration of room rest will be determined by the ventilation characteristics and local advice.

viii). The variation of individual practice, clinical rooms, room ventilation and local Covid rates in the community should all be given consideration in the prevention of viral infection. Local safety measures will need to be based on these considerations.
Appendix

The science behind the reasoning

Definitions:

Aerosol: suspension of fine solid or liquid droplets in a gas

Droplet: very small drop of liquid

These basic definitions look simple but aerosol science is much more complex; the definitions cannot therefore be applied as easily as may be expected.

For practical purposes, droplet sizes are categorised as follows:

- <5 μm ‘airborne’ particles
- >5 μm referred to as a droplet within Infection Control

Droplets that are 40 μm or less are not visible and would go unnoticed.
Droplets of 100 μm or less are inhalable.

For the purpose of this guidance document, we will refer specifically to respiratory aerosols. These will include a range of droplet size including microdroplets.

Viral particles may contaminate particles of all sizes but the viral load would be greater on a larger droplet.

The behaviour of the aerosol will depend on particle size and the environment. The latter includes temperature and humidity, but room airflow can have a significant effect of maintaining droplets in suspension and spread.
4 Aerosol generation

Endotracheal intubation is the only AGP that is proven to cause aerosolised viral transmission.\(^1\) This was described in a systematic review of the transmission of acute respiratory infections. Tracheostomy, non-invasive ventilation and bronchoscopy are implicated in aerosol generation, although not proven.

The four national public health bodies advise appropriate PPE, including fit-tested particulate respirators, when undertaking these procedures.\(^2\)

Flexible and rigid nasendoscopy (NE) have been identified as potential AGPs due to their similarities with bronchoscopy.

NE in itself is not an AGP, unlike intubation, in which high-pressure air forced into a patient’s mouth aerosolises moisture from their respiratory tract. In NE secretions can only be aerosolised by sneezing and coughing. Contact transmission can occur from secretions left on the endoscope after use, however the mechanism of this transmission is hand-to-mouth transfer rather than inhalation. Any respiratory infection (RSV, influenza, pneumonia, TB) can be transmitted by aerosolisation or contact transmission, and it is important to note that basic infection control precautions (gloves, hand washing and covering of the face when sneezing) were regarded as adequate before the arrival of Covid-19.

Breathing, coughing and sneezing produces different airflow dynamics dependent on the amount of kinetic energy involved. In descending order, sneezed airflow contains the most energy, followed by coughing and then breathing. The higher the energy involved, the larger the droplets that can be created (up to 400μm in sneezing). Aerosols from sneezing also have the highest exit velocity of up to 100m/s.\(^3\)

Droplets

Both droplet size and exit velocity are important factors that dictate how an aerosol behaves. High-energy airflow, however, does not create exclusively large droplet
aerosols. Sneezed aerosols can contain very small droplets too. Small droplets remain airborne and evaporate rapidly without ever landing on a surface (within two seconds for droplets <50μm). Despite very small droplets evaporating rapidly, these high exit velocities can force droplets out to six metres.\(^{(4)}\)

Larger airborne droplets (>125μm) are subject to gravity, landing on surfaces before evaporating. In a room with still air, friction prevents these droplets travelling significant distances. They land within two meters in a matter of seconds.\(^{(4,5)}\) As a basic principle the larger the droplet the higher the viral load and theoretically the higher the risk of infection.\(^{(6)}\) These large droplets are the most hazardous which is why social distancing, hand washing and cleaning surfaces are so important.

It is interesting to note that even breathing and talking produces aerosols. Breathing has the lowest airflow velocity and therefore always produces very small droplets less than 8 μm. They evaporate in a fraction of a second, very close to the subject’s face without ever landing on a surface. \(^{(4,6)}\)

Coughing produces droplets with kinetic properties between breathing and sneezing.

Respiratory droplets are made up of both solution and substrate. The solution (H\(_2\)O) evaporates leaving behind the substrate, which is mainly sodium chloride. Factors that improve evaporation theoretically reduce transmission risk. These include high temperature, low humidity and air movement in the room.

In respiratory viral infections the evaporated substrate/dry particulate matter (sometimes referred to as microdroplets) may also carry viral material. These dry viral particles are believed to be less contagious than those in droplets. They can stay airborne indefinitely, but their role in viral transmission is unproven.
Masks

Basic surgical masks (BSM) have been shown to reduce aerosolisation during coughing and speaking by 98.5%.(7)

Respirator masks such as FFP2 (N95) and FFP3 (N99) trap 94% and 99% respectively, of particles as small as 0.3μm.

Put simply, a BSM stops 99% of an aerosol coming out while an FFP3 mask stops 99% of an aerosol being breathed in. Preventing an aerosol with a BSM has the added benefit of reducing air and surface contamination in a room.

5 Ventilation characteristics of rooms used for AGPs

Ventilation for any enclosed workspace is necessary for human habitation (fresh air – replacement of O2 used and removal of CO2 build up). In the healthcare environment it is also necessary for removal of infectious, toxic or otherwise hazardous odours, aerosols, vapours, fumes and dust (Control of Substances Hazardous to Health (COSHH) regulations, and also the dilution and control of airborne pathogenic material.(8)

The Healthcare Technical Memorandum 03-01, published by the DOH (7), states that ‘ventilation is installed to protect staff from harmful organisms, and the patients and staff have a right to expect that it will be designed, installed and operated and maintained to standards that will enable it to fulfill its desired functions reliably and safely.’ This Memorandum further states that ‘the requirements to provide ventilation, implicit under The Health and Safety at Work Act 1974 and COSHH, have been made explicit by the Management of Health and Safety at Work Regulations 1999, the Workplace (Health and Safety and Welfare) Regulations 1992 and the Provisions and Use of Work Equipment Regulations 1998.’

HTM 03-01 mainly deals with the ventilation in a healthcare setting designed to reduce the air contaminants that might affect a patient, for example the design of operating
suite ventilation, as opposed to the ventilation needed to remove aerosolised SARS-CoV-2 from a patient who poses a risk to the healthcare worker, and subsequent patients in that room. However, it contains a great deal of information about principles of ventilation, and is used by all hospital estates departments as their reference document.

6 Types of ventilation

Ventilation may be passive (opening windows and doors) or active with some form of mechanical ventilation. Ventilation may be described by the fixed volume of air supplied to a room, usually expressed in terms of the resulting air changes per hour (ACH), or the volume of air supplied in order to maintain a specific pressure relationship between the room and the surrounding areas, or a combination of both.\(^8\)

Local exhaust ventilation (LEV), describes systems installed to prevent hazardous substances entering the general atmosphere of the room in which they are being used. This may be a capture hood, extractor ductwork or a fan. Examples are fume cabinets in labs, or sometimes in mortuary dissection suites.

6.1 Natural ventilation

Created by the effects of wind pressure, or temperature differences in environments, when doors or windows are open, or when there are vents or gaps in windows and doors. Impossible to maintain consistent flow rates, and ensure minimum ventilation rates will be achieved at all times.

If natural ventilation is ‘single-sided’, it will usually only be effective for a three-metre depth within the space.\(^8\) Often purpose fitted vents are needed to allow cross flow of ventilation. Cross flow ventilation can be enhanced by the use of fans (so called mixed-mode ventilation), but the path of the air must be clear, to allow flow.

In modern clinic rooms, window opening is often restricted, and insulation of the room is designed to prevent drafts and therefore airflow.
6.2 **Mechanical ventilation**

This may be extraction ventilation (e.g. extractor fan), supply only (creates positive pressure room, e.g. operating theatres) or supply and extraction.

Supply and extraction methods (often called balanced ventilation) are often used in treatment rooms, or windowless examination rooms, to maintain consistent air movement.

6.3 **Dilutional ventilation**

Dilutional ventilation, as it suggests, aims to dilute the hazardous substances by means of room air changes (ACH).

Appendix 1 contains the recommended air change rates for a variety of hospital environments taken from HTM 03-01, as well as the type of ventilation, and whether there is a positive, negative or equal pressure environment.

Of note, a general ward should have an air supply/natural ventilation with 6 ACH; operating theatres should have positive pressure ventilation with 25 ACH; a treatment/minor procedure room should have positive pressure ventilation with at least 10 ACH.

7 **Air changes per hour (ACH) and efficiency of removal of airborne contaminants**

The efficiency of airborne contaminant removal from a room is shown by data from Universite Catholique de Louvrain, Architecture de Hygeine Hospitaliere (please see Appendix 2). It details the number of minutes needed to remove 90%, 99% and 99.9% of contaminants at different air change per hour (ACH).

Of note, the data shows the following:
• At 6 ACH, it takes 46-69 minutes to remove 99% and 99.9% respectively (the time taken for almost complete room air change in a ward).
• At 10 ACH, it takes 28-41 minutes to remove 99% and 99.9% respectively (as may occur in a possible treatment room setting).
• At 25 ACH, it takes 11-17 minutes to remove 99% and 99.9% respectively (in an operating theatre setting).

Appendix 3 contains similar data from the American Center for Disease Control and Prevention.\(^{(10)}\)

8 Clean air paths (CAP)

Dilutional ventilation can be aided by means of clean airflow paths. This is where the air coming into the room flows across the area of hazard, and out through a separate vent. There should be no other object restricting the airflow apart from the hazard.

An example of this is the airflow in anaesthetic rooms where air often comes in through a high wall vent, and out via a low level vent, properly behind the anaesthetic machine to remove anaesthetic gases in the room. The laminar flow (ultra-clean ventilation) system in orthopaedic theatres is another example of clean air flow paths.

It has been reported that the most important contributing factor to contaminant transmission in enclosed and mechanically ventilated environments is the path between the contaminant source and the exhaust, and not the ACH as may be expected.\(^{(11)}\)

9 Validation of ventilation

For any new facility or for the assessment of an older facility, the hospital estates department, often via an external specialist contractor, should validate the ventilation system.
Thus, a designated endoscopy AGP room should be validated accordingly, and clean airflow paths (CAPs) can be identified and assessed. The details of this process can be requested from the hospital estates team.

10  **Pragmatic room and ventilation consideration for potential AGPs in ENT**

10.1  **AGPs in patients not suspected of being Covid-19 positive**

There is no fixed advice on the exact environment that is best to perform an AGP on a patient whose Covid-19 status is unknown.

It is now clearly established that patients with Covid-19 could have minimal or trivial symptoms and Covid-19 swabs may show false negative results. Therefore, all patients who undergo upper airway endoscopy should be treated as potentially Covid positive.

10.2  **AGPs in Covid-19 positive patients**

The WHO recommends that potential AGPs performed on patients with Covid-19 should be performed, whenever possible in negative pressure rooms with a minimum of 12 ACHs.\(^{12}\)

‘Apply airborne precautions when performing an aerosol-generating procedure. Ensure that healthcare workers performing aerosol-generating procedures (e.g. open suctioning of respiratory tract, intubation, bronchoscopy, cardiopulmonary resuscitation) use the appropriate PPE, including gloves, long-sleeved gowns, eye protection, and fit-tested particulate respirators (N95 or equivalent, or higher level of protection). A scheduled fit test should not be confused with a user’s seal check before each use.

Whenever possible, use adequately ventilated single rooms when performing aerosol-generating procedures, meaning negative pressure rooms with a minimum of 12 air changes per hour or at least 160 L/second/patient in facilities with natural ventilation.
Avoid the presence of unnecessary individuals in the room’.

11 Further research

Further research is needed to try and assess the safest environment for potential AGPs in ENT. Local exhaust ventilation, air extraction ventilation or portable air filtering units might offer benefit, but further advice and research is needed.
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<th>Ventilation</th>
<th>AC/hr</th>
<th>Pressure (Pascals)</th>
<th>Supply filter</th>
<th>Noise (NPR)</th>
<th>Temp (°C)</th>
<th>Comments (for further information see Chapter 4)</th>
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<td>F7</td>
<td>40</td>
<td>18–25</td>
<td></td>
</tr>
<tr>
<td>Treatment room</td>
<td>S</td>
<td>10</td>
<td>+ve</td>
<td>F7</td>
<td>35</td>
<td>18–25</td>
<td></td>
</tr>
<tr>
<td>Pharmacy aseptic suite</td>
<td>S</td>
<td>20</td>
<td>#</td>
<td>H14</td>
<td>–</td>
<td>18–22</td>
<td># See EGGMP (Orange guide) a</td>
</tr>
<tr>
<td>Category 3 or 4 containment room</td>
<td>#</td>
<td>&gt;20</td>
<td>#</td>
<td>H14*</td>
<td>–</td>
<td>18–22</td>
<td># See ACDP guide; *Filters in extract</td>
</tr>
<tr>
<td>Post-mortem room</td>
<td>S &amp; E</td>
<td>S = 10</td>
<td>–ve</td>
<td>G4</td>
<td>35</td>
<td>18–22</td>
<td>Provide clean air-flow path</td>
</tr>
<tr>
<td>Specimen store</td>
<td>E</td>
<td>–</td>
<td>–ve</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Pan accessible from outside of store</td>
</tr>
</tbody>
</table>

Notes: 18–22°C indicates the range over which the temperature may float.
18–22°C indicates the range over which the temperature should be capable of being controlled.
S = Supply
E = Extract
N = Natural ventilation
a = European guidelines on good manufacturing practice published by the Medicines and Healthcare products Regulatory Agency (MHRA)
### Table S3-1. Air changes per hour (ACH) and time in minutes required for removal efficiencies of 90%, 99%, and 99.9% of airborne contaminants

<table>
<thead>
<tr>
<th>ACH</th>
<th>90%</th>
<th>99%</th>
<th>99.9%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>138</td>
<td>276</td>
<td>414</td>
</tr>
<tr>
<td>2</td>
<td>69</td>
<td>138</td>
<td>207</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>92</td>
<td>138</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>69</td>
<td>104</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>55</td>
<td>83</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
<td>46</td>
<td>69</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>39</td>
<td>59</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>35</td>
<td>52</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>31</td>
<td>46</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
<td>28</td>
<td>41</td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>21</td>
<td>32</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>16</td>
<td>9</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>19</td>
<td>7</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>25</td>
<td>6</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>35</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>45</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

*This table has been adapted from the formula for the rate of purging airborne contaminants \((99\%)\). Values have been derived from the formula \(t_1 = [\ln (C_2 + C_1) - (Q + V)] \times 60\), with \(t_1 = 0\) and \(C_2 + C_1 = \text{removal efficiency} + 100\), and where:

\[
\begin{align*}
T_1 &= \text{initial timepoint} \\
C_1 &= \text{initial concentration of contaminant} \\
C_2 &= \text{final concentration of contaminants} \\
Q &= \text{air flow rate (cubic feet per hour)} \\
V &= \text{room volume (cubic feet)} \\
Q + V &= \text{ACH}
\end{align*}
\]

The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur, and the mixing factor could be as high as 10 if air distribution is very poor \((98)\). The required time is derived by multiplying the appropriate time from the table by the mixing factor that has been determined for the booth or room. The factor and required time should be included in the operating instructions provided by the manufacturer of the booth or enclosure, and these instructions should be followed.
Appendix 3 (10)

Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *

* This table is revised from Table S3-1 in reference 4 and has been adapted from the formula for the rate of purging airborne contaminants presented in reference 1435.

<table>
<thead>
<tr>
<th>ACH § ¶</th>
<th>Time (mins.) required for removal 99% efficiency</th>
<th>Time (mins.) required for removal 99.9% efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>138</td>
<td>207</td>
</tr>
<tr>
<td>4</td>
<td>69</td>
<td>104</td>
</tr>
<tr>
<td>6⁺</td>
<td>46</td>
<td>69</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>52</td>
</tr>
<tr>
<td>10⁺</td>
<td>28</td>
<td>41</td>
</tr>
<tr>
<td>12⁺</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>15⁺</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>20</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

† Denotes frequently cited ACH for patient-care areas.
§ Values were derived from the formula:

\[
t_2 - t_1 = - \left[ \ln \left( \frac{C_2}{C_1} \right) / (Q / V) \right] \times 60, \text{ with } t_1 = 0
\]

where

- \( t_1 \) = initial timepoint in minutes
- \( t_2 \) = final timepoint in minutes
- \( C_1 \) = initial concentration of contaminant
- \( C_2 \) = final concentration of contaminant
- \( C_2 / C_1 = 1 - (\text{removal efficiency} / 100) \)
- \( Q \) = air flow rate in cubic feet/hour
- \( V \) = room volume in cubic feet
- \( Q / V \) = ACH
Values apply to an empty room with no aerosol-generating source. With a person present and generating aerosol, this table would not apply. Other equations are available that include a constant generating source. However, certain diseases (e.g., infectious tuberculosis) are not likely to be aerosolized at a constant rate. The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur. Removal times will be longer in rooms or areas with imperfect mixing or air stagnation.

Caution should be exercised in using this table in such situations. For booths or other local ventilation enclosures, manufacturers’ instructions should be consulted.\(^{10}\)

References


**Droplet summary table**

<table>
<thead>
<tr>
<th>Droplet size</th>
<th>Small (&lt;50μm)</th>
<th>Large (50-400μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Produced by</strong></td>
<td>Breathing/cough/sneeze</td>
<td>Cough/sneeze</td>
</tr>
<tr>
<td><strong>Kinetics</strong></td>
<td>Remain airborne</td>
<td>Land within 2m</td>
</tr>
<tr>
<td><strong>Evaporation time</strong></td>
<td>Seconds</td>
<td>Minutes</td>
</tr>
<tr>
<td><strong>Viral load</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Filtered by FP2/3 mask</strong></td>
<td>94/99%</td>
<td>94/99%</td>
</tr>
</tbody>
</table>