Aerosol Generating Procedures (AGPs) within the ENT clinic


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Reviewed by specialty society presidents: BRS, BSFPS, BLA, Head & Neck, BAPO, BSO.

Introduction

Prior to the advent of the COVID-19, potential aerosol generating procedures (AGPs), such as Fibreoptic Nasal Endoscopy (FNE) and Laryngoscopy were an everyday part of the ENT clinic, typically performed with minimal or no Personal Protective Equipment (PPE). The key question many ENT Departments are asking is: what is the safest way to perform endoscopy of the nose and throat in the Outpatient clinic?

COVID-19 is still a new disease and there are still many unanswered questions, particularly with regard to transmission of infection. This has brought standard clinical practice into question. It is now clearly recognised that aerosols produced from coughing, sneezing and speech may be contaminated with SARS-CoV-2, thus potentially putting patients and healthcare staff at risk.

The droplet kinetic evidence used to produce this document is from lab-based experiments. Viral behaviour is borrowed from studies looking at influenza and coronaviruses other than COVID-19. We have made, what we feel are reasonable assumptions that the basic principles of viral transmission are transferrable to SARS-CoV-2, when looking at the ways to minimise risk of COVID-19 spread.

The following recommendations have been written after careful consideration of the science, balanced with practical aspects of clinical care, with the aim of creating workable, sensible advice to minimise the risk of viral infection. The document includes a review of the known principles of aerosolisation, environment and room ventilation that can be applied to local units.

Hopefully this will help ENT departments to work with their Hospital Trusts to create the best environment for these procedures to be performed in the most safe and efficient way. This document is based on the current science, but may be superseded in the future as new evidence about COVID-19 is discovered.

The basic principles of these guidelines are that procedures such as upper airway endoscopy can generate unexpected aerosol production, and become an AGP, whilst the procedure is being performed. The aerosol is potentially dangerous if the patient is infected with SARS-CoV-2.
If the patient is asymptomatic, apyrexial, wears a mask throughout the procedure and does not cough or sneeze at the time, then the current evidence seems to suggest that the risk of a dangerous aerosol will be minimal, and not greatly different from the aerosol produced with speech. However the procedure will always carry the potential to be a more significant AGP, if the patient does cough or sneeze.

Whilst we cannot assume that all such patients are infection free, or that an aerosol is not dangerous, we can minimize this risk or predict when there is a reasonable chance of aerosol production.

The guidance should also be helpful for other specialty groups that perform upper airway endoscopy, such as maxillofacial surgeons and oncologists.

Applying these principles will hopefully provide a balanced means of minimising the risk of SARS-CoV-2 viral infection whilst trying to maintain the functionality and the safe delivery of clinical services.

Objectives of these guidelines
The following recommendations are written with the aim of minimising risk to patients and healthcare staff while recognising the diagnostic importance of upper airway endoscopy in ENT patients.

We have considered a range of scenarios with regard to the risk of being exposed to an AGP with potential viral load in various settings, and present the potential relative risk in each case.

We acknowledge that some hospitals may not currently provide suitable clinical rooms for safe upper airway endoscopy to occur. Guidance on how to manage environments with higher risk is provided within this document.

Whilst being cognizant of the risk of delaying clinical examination, we have also considered the risk to clinicians, healthcare staff and their patients. We have tried to strike a balance between the desire to restart a more normal pre-COVID clinical practice and the potential risk of serious illness should clinicians work in environments that are potentially unsafe and patients must be examined in these areas.

Allowing surgeons to work, and patients to be examined, in high-risk environments is neither ethical nor acceptable. The employer should therefore make every effort to ensure that the work environment for endoscopic examinations is safe.

Summary of principles and recommendations

A Brief summary of recommendations
1  **Key principles**

1.1 A designated, suitably ventilated, AGP procedure room should be available within the outpatient clinic.

1.2 It is acknowledged that not all upper airway endoscopies will generate an aerosol or droplets, especially if the patient did not cough or sneeze.

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

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

2  **Summary of recommendations**

2.1 **The endoscopy room**
- The designated room should, at the very least, be well ventilated.
- Ideally, the endoscopy room should have mechanical negative ventilation with a known rate of Air Changes per Hour (ACH).

2.2 **The patient**
- COVID-19 symptoms should be excluded by a screening assessment prior to clinical examination.
- The patient should wear a surgical mask during the procedure.

2.3 **The endoscopic procedure**
- The surgeon should wear suitable PPE as described in section 3.4.1.
- The number of personnel in the room should be minimised where practical.
- Should the patient cough or sneeze during the procedure whilst wearing a surgical mask, any aerosol generated should be relatively contained. However, the current precautions as described above are recommended as we currently lack evidence of the actual risk to viral transmission.

2.4 **After the procedure**
- The surfaces should be cleaned after each procedure.
• The requirement for a ‘rest period’ for the room between cases will depend upon whether a significant aerosol was generated, and the room’s ventilation characteristics. This may therefore vary between patients and facilities.

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

B Consideration of individual risk factors

3 The endoscopic procedure

3.1 Prior to consultation and endoscopy

3.1.1 COVID-19 symptoms should be excluded prior to attendance and clinical examination. Assessment should include screening questions on arrival and possibly by telephone on the day before their attendance, according to local Trust policies.

3.1.2 At present, having negative nasal/oropharyngeal swabs is not a recommendation. Rapid PCR may be ideal but it is not freely available in most units. Local Trust policies should be followed.

3.2 Minimising the risk of generating an aerosol

3.2.1 Prior to endoscopy, the patient should be counselled not to talk and to try to avoid coughing or sneezing during the procedure.

3.2.2 The risk of aerosol production should be minimised by the patient wearing a surgical mask.

3.2.3 It has been suggested that introducing the endoscope through a small cut made in the front surface of the facemask should further minimise the potential for droplet spread during the procedure. While this cannot be validated at present, it does seem to be a sensible option.

3.2.4 An aerosol that may potentially carry SARS-CoV-2 virus is most likely to occur should the patient suddenly cough or sneeze during endoscopy. The scientific evidence to date concludes that coughing produces a less significant aerosol than sneezing.

The current evidence suggests that, in the absence of coughing or sneezing, the risk of an aerosol is probably no greater than that generated during talking.
3.3 Appropriate PPE

3.3.1 The surgeon should wear suitable PPE during the procedure. This should include a respirator facemask, gloves, eye protection/visor and water-resistant long-sleeved gown (please see PHE guidance). The FFP3 mask offers the greatest protection against viral infection and is the recommended gold standard. In some instances we recognize that FFP3 masks maybe in short supply, but the absolute minimum should be an FFP2 mask in the absence of available FFP3 masks. PPE should ideally be donned before entering the AGP room.

3.3.2 A single respirator facemask may be worn for multiple endoscopies by the same surgeon/health care professional throughout a single session.

3.4 The endoscopy

3.4.1 The use of local anaesthetic/decongestant spray for rigid/flexible endoscopy is not clearly standardised and remains controversial. While nasal decongestion of the nose often enhances clinical diagnosis, and anaesthesia typically reduces patient discomfort, controversy remains about the risk of inducing unexpected episodes of coughing and sneezing. Ideally if this is to be used, there should be a period of approximately 10mins to allow the local anaesthetic to be effective before proceeding to endoscopy. The application of such local anaesthetic sprays or preparations remains at the discretion of the clinician.

3.4.2 The surgeon/health care professional may be relatively close to the patient during the procedure, and should try to distance himself or herself to avoid unexpected contamination from large droplets should the patient cough or sneeze.

3.4.3 Nasal and/or laryngeal endoscopy should, if possible, be observed on a separate video screen to allow the operator to maintain distance between himself/herself and the patient.

3.4.4 Single-use disposable flexible endoscopes are currently being used by some departments for emergency or routine use. The risk of generating AGPs during the procedure is the same as for re-usable endoscopes.

3.4.5 Single-use endoscopes are disposable and do not need decontamination.

3.4.6 However, the potential risk of SARS-Cov-2 transmission associated with endoscope decontamination should be minimal if recommended guidelines are followed (please see: PPE for nasal endoscope decontamination during the COVID-19 pandemic).
Factors to consider for the designated endoscopy room

4.1 Designated endoscopy rooms
4.1.1 Upper airway endoscopy that may generate an AGP should be performed in a separate designated room within the clinic.

4.1.2 The designated room(s) should be approved by consultation with the hospital’s estates team and infection control team, placing attention on the optimum ventilation, ACHs and clean air paths.

4.1.3 No unnecessary furniture or items in the room.

4.1.4 No unnecessary persons should be in the room during the procedure.

4.1.5 Surfaces should be wiped down with disinfectant between patients.

4.2 Assessment of ventilation
Any room that is going to be used for upper airway endoscopy with the potential for an AGP should be assessed with the help of the hospital estates department.

This assessment should include:

- type of ventilation that occurs within that room
- where ventilation input and outflow occurs
- number of air changes per hour (ACHs)
- whether there is positive, negative or equal pressure in the room
- if mechanical ventilation is present and functioning, the clean air path (CAP) should be determined.

4.3 Ventilation of the designated AGP room
4.3.1 Non-ventilated and naturally ventilated rooms are not ideal for upper airway endoscopy where the potential for generating an aerosol exists.

4.3.2 However, the suitability of the room chosen for endoscopy will vary amongst departments and ideal rooms may not currently be available. A pragmatic view is therefore necessary. A room that has reasonable ventilation may well be deemed to be acceptable in the absence of any other alternative.

4.3.3 Room environments with less than ideal ventilation characteristics will increase the risk of aerosol contamination of the staff and patients and this risk must be
acknowledged and approved by the Trust Estates Department, The Infection Prevention Control Team and Senior Trust Management.

4.3.4 The ventilation characteristics of dedicated endoscopy rooms determines the relative risk should an aerosol with a viral load be generated. The relative risk to healthcare staff and patients has been considered as follows:

**Relatively High Risk**
Rooms with no ventilation, natural ventilation, or re-circulating air conditioning units (ACUs) are not ideal for AGPs.

**Relatively Low Risk**
Rooms with mechanical ventilation or air conditioning units (ACUs) that extract and replace the room air by negative pressure are to be recommended.

4.3.5 Rooms that change the air content multiple times per hour are ideal. It takes approximately 5-6 Air Changes for 99%+ of airborne contaminants to be removed. The time taken to replace air for any individual room will depend on local variants and the air changes per hour (ACH). Infection prevention and control (IPC) and technical advice should be sought regarding the ACH for the designated endoscopy room.

4.3.6 The requirement for a ‘rest period’ of the examination room after an endoscopy will depend upon whether the patient has potentially produced a significant aerosol by coughing or sneezing, together with the ventilation characteristics of the room. If a patient has not produced a significant aerosol, and the room has a high ACH, the rest period may be minimal. Local advice from the Director of Infection Prevention Control should be sought.

4.3.7 Consideration should be given to ‘the clean air path’ (CAP) within the designated room. If possible, a patient undergoing the AGP should be situated between the inflow and outflow path of ventilation with no other obstruction to flow between those points.

4.4 The Unsatisfactory Designated Endoscopy Room

4.4.1 Should the designated endoscopy room be considered unsafe due to ventilation characteristics, clinicians should consider the risks to patients, themselves and other healthcare staff.

4.4.2 The clinician should consider deferring the endoscopy until this can be performed in a more suitable environment.

4.4.3 Concerns should be raised urgently with Infection Prevention Control (IPC) and the Trust Estates Department.
4.4.4 The room should be modified or changed according to local circumstance.

4.4.5 Consideration should be given to the use of portable extraction units, or fitting the room with dedicated long-term extraction and ventilation following expert advice.

C Appendix: The science behind the reasoning

5 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 sizes 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.

6 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 aerosolized 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, handwashing 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. Sneeze 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 6m.\(^{(4)}\)

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 2 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 ($H_2O$) 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.

**7 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, or 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”.\(^{(8)}\)
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.

8 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.

8.1 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 3 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.

8.2 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.

8.3 **Dilutional ventilation**

Dilutional ventilation, as the term suggests, aims to dilute 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 or natural ventilation with 6 ACH; operating theatres should have positive pressure ventilation with 25 ACH; a treatment or minor procedure room should have positive pressure ventilation with at least 10 ACH.

9 **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).\(^9\) 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 that:

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.\(^10\)

10 **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 airflow paths.

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

### 11 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.

### 12 Pragmatic room and ventilation consideration for potential AGPs in ENT
#### 12.1 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 positive negative results. **Therefore, all patients who undergo upper airway endoscopy should be treated as potentially COVID positive.**

#### 12.2 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.”

13 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>Pressure (Pascals)</th>
<th>Supply filter</th>
<th>Noise (NR)</th>
<th>Temp (°C)</th>
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<td>18-25</td>
<td></td>
</tr>
<tr>
<td>Endoscopy cleaning</td>
<td>E</td>
<td>&gt;10</td>
<td>–ve</td>
<td>–</td>
<td>40</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Day-case theatre</td>
<td>S</td>
<td>15</td>
<td>+ve</td>
<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 septic suite</td>
<td>S</td>
<td>20</td>
<td>#</td>
<td>H14</td>
<td>–</td>
<td>18-22</td>
<td># See EGGMP (Orange guide)</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 ACPD guide: *Filter in extract</td>
</tr>
<tr>
<td>Post-mortem room</td>
<td>S &amp; E</td>
<td>S = 10</td>
<td>E = 12</td>
<td>–ve</td>
<td>G4</td>
<td>35</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)
### Appendix 2 (9)

**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 \( t_1 = \left[ \ln \left( \frac{C_2 - C_1}{Q + V} \right) \right] \times 60, \) with \( t_1 = 0 \) and \( C_2 - C_1 \) (removal efficiency + 100), and where:

\[
\begin{align*}
  t_1 &= \text{initial time point} \\
  C_1 &= \text{initial concentration of contaminant} \\
  C_2 &= \text{final concentration of contaminants} \\
  Q &= \text{air flow rate (cubic feet per hour)} \\
  V &= \text{room volume (cubic feet)} \\
  Q + V &= \text{ACH}
\end{align*}
\]

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 (99). 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.
### Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *

<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>

* 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.

+ Denotes frequently cited ACH for patient-care areas.

§ Values were derived from the formula:

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

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 aerosolised 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.\(^{213}\) 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>'Produced by</td>
<td>Breathing/cough/sneeze</td>
<td>Cough/sneeze</td>
</tr>
<tr>
<td>Kinetics</td>
<td>Remain airborne</td>
<td>Land within 2m</td>
</tr>
<tr>
<td>Evaporation time</td>
<td>Seconds</td>
<td>Minutes</td>
</tr>
<tr>
<td>Viral load</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Filtered by FP2/3 mask</td>
<td>94/99%</td>
<td>94/99%</td>
</tr>
</tbody>
</table>