Evidence summary: What is the risk of using laminar airflow in operating theatres when operating on a COVID-19 patient? [v2.0]

The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

YOUR QUESTION

What is the risk of using laminar airflow in operating theatres when operating on a COVID-19 patient?

IN A NUTSHELL

Ventilation in both laminar flow and conventionally ventilated theatres should remain fully on during surgical procedures where patients have suspected or confirmed COVID19 infection[1,4]. Aerosols which may be generated as a result of AGPs will be localised and rapidly diluted by operating theatre ventilation. Air passing from operating theatres to adjacent areas will be highly diluted and is not considered to be a risk. Local risk assessment may dictate that a neutral pressure theatre or negative pressure theatre is preferred for COVID19 procedures[1].

Ti et al[7] describe an operating room configuration in Singapore in which the prep, scrub and operating room proper are positive pressure areas designed to reduce surgical site infections. The anesthesia induction room and ante room are negative pressure areas. These serve as a barrier to prevent contaminated air leaving the operating room and external pathogens entering the operating room.

In earlier studies, Chow et al[9,10,11] assert that a negative-pressure operating theater is required to limit the spread of respiratory diseases in patients with SARS, tuberculosis or similar infectious diseases. Airflow performance in the negative-pressure operating theater effectively controlled the dispersion of infectious particles. Air velocity at the supply diffuser has been identified as one of the most important factors in governing the dispersion of airborne infectious particles. Higher velocity within the laminar regime is advantageous in minimizing the heat-dissipation effect and to ensure an adequate washing effect against particulate settlement. The authors emphasize that a successful outcome in preventing airborne infection depends as much on resolving human factors as on overcoming technical obstacles.

IRISH AND INTERNATIONAL GUIDANCE

Health Protection Surveillance Centre (8 April 2020) Interim Infection Prevention and Control Precautions for Possible or Confirmed COVID-19 in a Pandemic Setting[1]

The decision that surgery is essential during the period of infectivity for a patient with confirmed COVID-19 should be made by senior surgeons and anaesthetists. Wherever possible, surgery should be deferred until the patient is no longer infectious and is in optimal condition for surgery. Ventilation in both laminar flow and conventionally ventilated theatres should remain fully on during surgical procedures where patients have suspected or confirmed COVID19 infection.

- Aerosols which may be generated as a result of AGPs will be localised and rapidly diluted by operating theatre ventilation.
- Air passing from operating theatres to adjacent areas will be highly diluted and is not considered to be a risk.
- Local risk assessment may dictate that a neutral pressure theatre or negative pressure theatre is preferred for COVID19 procedures (Appendix 4)

The patient should be transported directly into the operating theatre and should wear a surgical mask if it can be tolerated. The operating theatre staff must be informed in advance of a patient transfer of a confirmed or possible COVID-19 case. The patient should be reviewed, anaesthetised, intubated, extubated and recovered in the operating theatre. Appropriate PPE should be worn by staff present in the theatre when AGP are performed: eg intubation, extubation. If the operative procedure is anticipated to involve an AGP, as described in the section on AGP, all staff present in the theatre for the duration of the surgery must wear appropriate PPE for an AGP scenario. Entry and exit from the room should be minimised during the procedure. Disposable anaesthetic equipment should be used where possible. The anaesthetic machine must be protected by a filter with viral efficiency to 99.99%. The operating theatre should be cleaned, as per local policy, paying particular attention to hand contact points: eg on the anaesthetic machine. Instruments and devices should be decontaminated in the normal manner in accordance with manufacturer's advice.

What does the World Health Organization say?

World Health Organization (2020). Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations[2]
Respiratory infections can be transmitted through droplets of different sizes: when the droplet particles are >5-10μm in diameter they are referred to as respiratory droplets; and when then are <5μm in diameter, they are referred to as droplet nuclei. According to current evidence, COVID-19 virus is primarily transmitted between people through respiratory droplets and contact routes. In an analysis of 75,465 COVID-19 cases in China, airborne transmission was not reported.
Droplet transmission occurs when a person is in in close contact with someone who has respiratory symptoms such as coughing or sneezing and is therefore at risk of having mucosae [mouth and nose] or conjunctiva [eyes] exposed to potentially infective respiratory droplets. Transmission may also occur through fomites in the immediate environment around the infected person. Therefore, transmission of the COVID-19 virus can occur by direct contact with infected people and indirect contact with surfaces in the immediate environment or with objects used on the infected person: eg stethoscope or thermometer.
Airborne transmission is different from droplet transmission as it refers to the presence of microbes within droplet nuclei, which are generally considered to be particles <5μm in diameter, can remain in the air for long periods of time and be transmitted to others over distances greater than 1m. In the context of COVID-19, airborne transmission may be possible in specific circumstances and settings in which procedures or support treatments that generate aerosols are performed: ie endotracheal intubation, bronchoscopy, open suctioning, administration of nebulized treatment, manual ventilation

before intubation, turning the patient to the prone position, disconnecting the patient from the ventilator, non-invasive positive-pressure ventilation, tracheostomy, and cardiopulmonary resuscitation.
* There is no specific guidance on the use of laminar airflow when operating on a COVID-19+ patient.

What do the Centers for Disease Control and Prevention (United States) say?

Centers for Disease Control and Prevention (2003) Background C. Air : Guidelines for Environmental Infection Control in Health-Care Facilities[3]
CDC references the Guidelines for Environmental Control in Healthcare Facilities: Background C. Air. Includes ventilation although these are not COVID-19 specific.
* There is no specific guidance on the use of laminar airflow when operating on a COVID-19+ patient.

[Newly added] Public Health England (2020) Reducing the risk of transmission of COVID-19 in the hospital setting[4]
Section 8: Operating Theatres
It is recommended that ventilation in both laminar flow and conventionally ventilated theatres should remain fully on during surgical procedures where patients may have COVID-19 infection.

Zhejiang University (2020) Online-Handbook of COVID-19 Prevention and Treatment Chapter 8 Surgical Operations for Suspected or Confirmed Patients[5]
Describes the procedures followed at the First Affiliated Hospital of Zhejiang University before, during and after operating on suspected or confirmed COVID-19 patient.

INTERNATIONAL LITERATURE

What does the international literature say?

[Newly added] Steward et al (2020). Urologic surgery and COVID-19: how the pandemic is changing the way we operate[6]

The coronavirus disease 2019 (COVID-19) pandemic has had a global impact on all aspects of healthcare, including surgical procedures. For urologists, it has affected and will continue to influence how we approach the care of patients pre-operatively, intra-operatively and post-operatively. A risk-benefit assessment of each patient undergoing surgery should be performed during the COVID-19 pandemic based on the urgency of the surgery and the risk of viral illness and transmission. Patients with advanced age and comorbidities have a higher incidence of mortality. Routine preoperative testing and symptom screening is recommended to identify those with COVID-19. Adequate personal protective equipment for the surgical team is essential to protect healthcare workers and ensure an adequate workforce. For COVID-19 positive or suspected patients, the use of N95 respirators is recommended if available. The anesthesia method chosen should attempt to minimize aerosolization of the virus. Negative pressure rooms are strongly preferred for intubation/extubation and other aerosolizing procedures. Although transmission has not yet been shown during laparoscopic and robotic procedures, efforts should be made to minimize the risk of aerosolization. Ultra low particulate air filters are recommended for use during minimally invasive procedures to decrease the risk of viral transmission. Thorough cleaning and sterilization should be performed post-operatively with adequate time allowed for the operating room air to be cycled after procedures. COVID-19 patients should be separated from non-infected patients at all levels of care including recovery to decrease the risk of infection. Future directions will be guided by outcomes and infection rates as social distancing guidelines are relaxed and more surgical procedures are reintroduced. Recommendations should be adapted to the local environment and will continue to evolve as more data becomes available, the shortage of testing and PPE is resolved and a vaccine and therapeutics for COVID-19 are developed.

Ti et al (2020) What we do when a COVID-19 patient needs an operation: operating room preparation and guidance[7]

The first case of COVID-19 in Singapore was confirmed on 23 January 2020. In the week of February 13–19, the World Health Organization reported that Singapore had more cases of COVID-19 than any other country outside of mainland China. We wish to share the protocol that we use in our hospital in preparing an operating room (OR) for confirmed or suspected COVID-19 patients coming for surgery. An OR with a negative pressure environment located at a corner of the operating complex, and with a separate access, is designated for all confirmed or suspected COVID-19 cases. The OR actually consists of five interconnected rooms, of which only the ante room and anesthesia induction rooms have negative atmospheric pressures. The OR proper, preparation and scrub rooms all have positive pressures. Understanding the airflow within the OR is crucial to minimizing the risk of infection.

The prep, scrub, and operating room proper are positive pressure areas designed to reduce surgical site infections. The anesthesia induction room and ante room are negative pressure areas. These serve as a barrier to prevent contaminated air leaving the operating room and external pathogens entering the operating room.

Vonci et al (2019) Association between air changes and airborne microbial contamination in operating rooms[8]

Control of airborne microbial contamination is important in operating rooms. To keep airborne contamination low, guidelines should highlight the importance of air turnover. The aims of this study are: 1. to verify the association between air turnover and airborne contamination in ORs; and 2. to identify a statistical relationship between air turnover and airborne microbial contamination. A cross-sectional study was carried out from November 2014 to July 2017 in Siena Hospital. 19 ORs—14 with turbulent and 5 with laminar flow ventilation—were surveyed a total of 59 times under operating conditions. Air samples were collected with an air sampler. Petri dishes incubated at 36°C for 48 hours were used to quantify colony forming units in the samples. The data was transformed to evaluate several statistically significant nonlinear associations between air turnover, quantified as air changes per hour (ACH) and CFU per cubic meter of air ($p < 0.05$). A log-linear regression model provided the best fit between ACH and CFU for laminar ($p = 0.013$; R2 = 0.3911) and turbulent flow systems

(p = 0.002; R2 = 0.3443). The corresponding model was:
ln(CFU) = (a – b*ACH), where the regression parameters were estimated at a = 4.02 and b = 0.037 for laminar flow and a = 5.24 and b = 0.067 for turbulent flow. Italian guidelines indicate microbial load limits of 20 and 180 CFU/m3 for operating rooms with laminar and turbulent flow ventilation respectively. The model allowed us to evaluate the minimum number of ACHs to keep CFU within these limits. Ad hoc measurements in other environments can be used to calibrate the relationship between ACH and CFU.

Chow et al (2006a) A computer evaluation of ventilation performance in a negative-pressure operating theater[9]

A negative-pressure operating theater is required to limit the spread of respiratory diseases in patients with severe acute respiratory syndrome, tuberculosis, avian influenza or similar infectious diseases. In Hong Kong, we converted a conventional operating theater into a negative-pressure operating theater that has been in service for more than a year. In this article, we introduce its ventilation design and evaluate the airflow performance in relation to different combinations of medical lamp configurations and modes of launching infectious particles into the room air.
Our analyses showed that the airflow performance in the negative-pressure operating theater was satisfactory and comparable to the original positive-pressure design. The airflow pattern effectively controlled the dispersion of infectious particles. Our calculations demonstrated that the airflow contained the dispersion of infectious particles released from the patient sufficiently to protect the surgical team, and vice versa. In conclusion, computational fluid dynamics can be used to assess airflow in a negative-pressure operating room and model the dispersion of infectious particles from the patient.

Chow et al (2006b) Conversion of operating theatre from positive to negative pressure environment[10]

The severe acute respiratory syndrome (SARS) crisis led to the construction of a negative pressure operating theatre at a hospital in Hong Kong. It is currently used for treatment of suspected or confirmed airborne infection cases and was built in anticipation of a return of SARS or other respiratory epidemics. This article describes the physical conversion of a standard positive pressure operating theatre into a negative pressure environment, problems encountered, airflow design, and evaluation of performance. Since entering regular service, routine measurements and observations have indicated that the airflow performance has been satisfactory. This has also been confirmed by regular air sampling checks. Computational fluid dynamics was used to compare the distribution of room air before and after the design changes from positive to negative pressure. The simulation results show that the physical environment and the dispersion pattern of bacteria in the negative pressure theatre were as good as if not better than those in the original positive pressure design.

Chow and Yang (2005) Ventilation performance in the operating theatre against airborne infection: numerical study on an ultra-clean system[11]
A laminar airflow study was performed in a standard operating theatre in Hong Kong, the design of which followed the requirements of the UK Health Technical Memorandum. The study of the ultra-clean ventilation system investigated the effectiveness of the laminar flow in: 1. preventing bio aerosols released by the surgical staff from causing postoperative infection of the patient; and 2. protecting the surgical team against infection by bacteria from the wound site. Seven cases of computer simulation are presented and the sensitivity of individual cases is discussed. Air velocity at the supply diffuser has been identified as one of the most important factors in governing the dispersion of airborne infectious particles. Higher velocity within the laminar regime is advantageous in minimizing the heat-dissipation effect and to ensure an adequate washing effect against particulate settlement. Inappropriate positioning of medical lamps can be detrimental. Omission of a partial wall may increase the infection risk of the surgical team due to the ingression of room air at the supply diffuser periphery. The authors emphasize that a successful outcome in preventing airborne infection depends as much on resolving human factors as on overcoming technical obstacles.

Chee et al (2004) Infection control measures for operative procedures in severe acute respiratory syndrome-related patients[12]
Singapore reported its first case of SARS in early March 2003 and was placed on the World Health Organization list of SARS-affected countries on March 15, 2003. During the outbreak, Tan Tock Seng Hospital was designated as the national SARS hospital in Singapore to manage all known SARS patients. Stringent infection control measures were introduced to protect healthcare

workers and control intra-hospital transmission of SARS. Workflow processes for surgery were extensively modified. The authors describe the development of infection control measures, the conduct of surgical procedures, and the management of high-risk procedures during the SARS outbreak. Forty-one operative procedures including 15 high-risk procedures were performed on SARS-related patients. 124 healthcare workers had direct contact with SARS patients during these procedures. There was no transmission of SARS within the operating room complex. Staff personal protection, patient risk categorization and reorganization of operating room workflow processes formed the key elements for the containment of SARS transmission.

Wong et al (2020) Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore[13]

The coronavirus disease 2019 (COVID-19) outbreak has been designated a public health emergency of international concern. To prepare for a pandemic, hospitals need a strategy to manage their space, staff and supplies so that optimum care is provided to patients. In addition, infection prevention measures need to be implemented to reduce in-hospital transmission. In the operating room, these preparations involve multiple stakeholders and can present a significant challenge. Here, we describe the outbreak response measures of the anesthetic department staffing the largest academic tertiary level acute care hospital in Singapore and a smaller regional hospital. These include engineering controls such as identification and preparation of an isolation operating room, administrative measures such as modification of workflow and processes, introduction of personal protective equipment for staff, and formulation of clinical guidelines for anesthetic management. Simulation was valuable in evaluating the feasibility of new operating room set-ups or workflow. We also discuss how the hierarchy of controls can be used as a framework to plan the necessary measures during each phase of a pandemic and review the evidence for the measures taken. These containment measures are necessary to optimize the quality of care provided to COVID-19 patients and to reduce the risk of viral transmission to other patients or healthcare workers.

Other

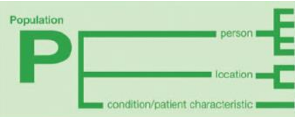
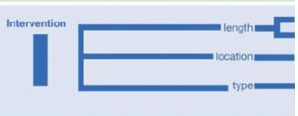
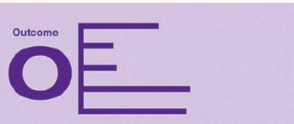
Schoen and Hodgson (2020) ASHRAE Position Document on Airborne Infectious Diseases[14]

[COMMERCIAL]

Infectious diseases spread by several different routes. Tuberculosis and in some cases influenza, the common cold and other diseases spread by the airborne route. The spread can be accelerated or controlled by heating, ventilating and air-conditioning (HVAC) systems, for which ASHRAE is the global leader and foremost source of technical and educational information. ASHRAE will continue to support research that advances the state of knowledge in the specific techniques that control airborne infectious disease transmission through HVAC systems, including ventilation rates, airflow regimes, filtration and ultraviolet germicidal irradiation (UVGI). ASHRAE's position is that facilities of all types should follow as a minimum the latest practice standards and guidelines. ASHRAE's 62.X Standards cover ventilation in many facility types, and Standard 170 covers ventilation in health-care facilities. New and existing healthcare intake and waiting areas, crowded shelters and similar facilities should go beyond the minimum requirements of these documents, using techniques covered in ASHRAE's Indoor Air Quality Guide (2009) to be even better prepared to control airborne infectious disease including a future pandemic caused by a new infectious agent.

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at 08 May 2020.This evidence summary collates the best available evidence at the time of writing. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.

The following PICO(T) was used as a basis for the evidence summary:

	SUSPECTED OR CONFIRMED COVID-19 PATIENT
	SURGICAL OPERATION
	
	INFECTION CONTROL

The following search strategy was used:

"coronaviridae"[MeSH Terms] OR "covid-19" OR coronavirus OR "wuhan virus" OR "2019-ncov" OR "severe acute respiratory syndrome coronavirus 2" OR "2019 novel coronavirus" OR "2019 new coronavirus" OR sars or "severe acute respiratory syndrome"
AND
"Operating Rooms"[Mesh] OR "operating room" or "operating theatre" or "operating rooms" or "operating theatres" or "operating theater" or "operating theaters" OR laminar

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BMJ Best Practice

Cochrane Clinical Answers

[1] Health Protection Surveillance Centre (8 April 2020) Interim Infection Prevention and Control Precautions for Possible or Confirmed COVID-19 in a Pandemic Setting. https://www.hpsc.ie/a-z/respiratory/coronavirus/novelcoronavirus/guidance/.
[2] World Health Organization (2020) https://www.who.int/publications-detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations
[3] Centers for Disease Control and Prevention (2003) https://www.cdc.gov/infectioncontrol/guidelines/environmental/background/air.html#c5c%20%20(section%20c)
[4] Public Health England (2020) Reducing the risk of transmission of COVID-19 in the hospital setting https://www.gov.uk/government/publications/wuhan-novel-coronavirus-infection-prevention-and-control/reducing-the-risk-of-transmission-of-covid-19-in-the-hospital-setting
[5] Zhejiang University. (2020) Online-Handbook of COVID-19 Prevention and Treatment https://www.alnap.org/help-library/handbook-of-covid-19-prevention-and-treatment

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[11] Chow TT, Yang XY. Ventilation performance in the operating theatre against airborne infection: numerical study on an ultra-clean system. *J Hosp Infect*. 2005;59(2):138- 147. doi:10.1016/j.jhin.2004.09.006
[12] Chee VW, Khoo ML, Lee SF, Lai YC, Chin NM. Infection control measures for operative procedures in severe acute respiratory syndrome-related patients. *Anesthesiology*. 2004;100(6):1394- 1398. doi:10.1097/00000542-200406000-00010
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[14] ASHRAE. (2020) https://www.ashrae.org/File%20Library/About/Position%20Documents/Airborne-Infectious-Diseases.pdf