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Organizing a safe operating room during a pandemic. What did we learn from COVID-19?

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Abstract : During the COVID-19 pandemic, multiple guidelines have been issued on hospital safety and protection measures to prevent transmission to healthcare workers and to other patients. The operating room is a high-risk environment where enhanced precautions are required. The guidelines differ and practical implementation between hospitals can also vary, according to interpretation and budget. Staff at risk may question if the local policies are sufficient and correct. This article provides an overview and theoretical background to the additional safety measures required in the operating room during a viral pandemic like the COVID-19 pandemic. This may serve as a touchstone and tool for anesthetists and OR managers.

Key words : Safety ; coronavirus ; breathing circuit filter ; PPE ; OR management.

Introduction

During early 2020, healthcare institutions across Europe have been inundated by patients suffering from coronavirus disease (COVID-19). It was caused by a novel coronavirus (2019-nCoV, later SARS-CoV-2) originating in Wuhan, China. The high number of patients requiring long hospital and ICU admission placed an enormous pressure on healthcare systems. Italy became a devastating European example, where the pandemic hit early and hard, making health care providers struggle with shortage of logistics and supplies and exhaustion of staff due to illness.

All European countries started to prepare and organize for an impending disaster. Hospitals invested in reorganization of services and expansion of ICU beds to prepare for high numbers of patients suffering from COVID-19. Safety guidelines were implemented to protect against cross-contamination of staff and logistics, and staff were urgently prepared for work in emergency or ICU care. Incredible organizational work has been performed in a very short time interval.

With this there has been a huge tsunami of information for health care workers, often updated daily. Leading international and national organizations, including the World Health Organization (WHO), the European Society of Intensive Care Medicine (ESICM), the European Centre for Disease Prevention and Control (ECDC), the Centers for Disease Control and Prevention (CDC), alongside national societies have provided guidelines. However, the finetuning and practical implementation has varied among hospitals. This has resulted in a feeling of uncertainty and doubt amongst caregivers with the Chinese and Italian experience emphasizing the high risk of transmission to health care workers (HCW).

In the early organizational phase hospital crisis teams focused on the emergency department, hospital admission units and intensive care expansion. Providing a safe working environment in the operating room for patients and staff is also of paramount importance, with high numbers of infectious symptomatic, as well as infectious asymptomatic patients, presenting for urgent and emergency surgery.

This article summarizes the technical details needed for organizing a safe operating room, not only during this pandemic, but it can give guidance in case of future pandemics.

Transmission

Understanding the mode of transmission of the etiologic agents is essential when preparing

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the working environment. The novel coronavirus SARS-CoV-2 is mainly transmitted through large respiratory droplets and contact transmission (with infected persons, objects or surfaces), but other modes of transmission have also been proposed (1-3). Sneezing or coughing produces mainly large droplets >5mm up to 1m (3 feet) around a patient. Examples of other pathogens spread in this way are Influenza, RSV and adenoviruses. Because the droplets tend to fall to the ground quite quickly, measures to control air flow are not indicated (4). Airborne spread means small residuals of droplets, 'droplet nuclei' are suspended in the air, subsequently dry and produce particles ranging in size from 1-5 μm, containing possible viable micro-organisms e.g. Mycobacterium tuberculosis, Varicella Zoster virus, that can remain suspended in the air and be transported over longer distances (4, 5). Droplet nuclei can be deposited into the lower respiratory tract when inhaled, in contrast to larger droplets.

Pathogens normally transmitted only by contact or by droplets, can become airborne under certain conditions, during so-called 'aerosolization'. This requires high velocity flows of liquid and air. These accelerated flows can be generated during invasive medical interventions, such as e.g. in- and extubation, bronchoscopy or tracheal suction. Such procedures are described as 'aerosol generating procedures – AGPs'(5, 6). Very few viruses can become airborne, thus meaning they remain in an infective state in droplet nuclei caused by aerosol, and factors facilitating this are unknown. One requirement is a sufficient 'viral load' suspended in the aerosolized particles. In the context of the SARS-CoV-2, airborne transmission may be possible but this is controversial (7, 8). As this is a new virus, evidence on possible modes of transmission had to be obtained during the course of the pandemic itself. In our opinion, safety measures against the most invasive way of transmission possible should be taken until proven otherwise. As such during the first phase of the COVID-19 pandemic protection against airborne transmission is advised when performing AGP's as there is no clear evidence that the SARS-CoV-2 doesn't spread airborne.

Likewise the WHO advises precautions against droplet and contact transmission, and against airborne transmission during and shortly after AGP's (2).

Viral RNA has also been detected in feces, the significance of this finding has yet to be determined. Blood-borne transmission is not regarded an important source of transmission (9).

Operating Room Management

During a pandemic the management and protection of medical personnel is of great importance since the amount of available HCW in the operating room is limited. Obviously, prevention of transmission to other admitted patients is of upmost importance as well.

Performing cases of a confirmed infected patient in a dedicated operating room is strongly advised, as all preparations to prevent cross-contamination can be made well in advance. This operating room should be easily accessible and ideally have a preparation room for donning and doffing personal protective equipment. All unnecessary equipment, as well as the anesthesia tray, should be removed from the OR. An 'outside' nurse should be appointed to hand over supplies if needed. Unremovable equipment can be covered with plastic, water-resistant sheets. As the pandemic evolves it may become necessary to expand the number of dedicated OR's.

Different access ways to the operating room for infected and non-infected patients should be provided. While waiting for surgery, contaminated patients have to be placed in an isolation room, preferably as close as possible to the dedicated operating room with the least passage through non-contaminated parts of the hospital. If possible recover the patient in the operating room or otherwise in an isolation room (10).

Aim for as few different people as possible working daily in the operating room (e.g. longer shifts) to reduce the use of surgical masks and to reduce potential exposure. This may mean interns or residents are excluded and teaching opportunities missed.

Do 1 case in an OR, followed by terminal cleaning, with the second case in another OR and switch between OR's (10).

If the surgeon (proceduralist) will be operating later in the day and is scheduled for only 1 procedure, provide notification when there is the start of closure of the preceding case being done by the anesthesia and nursing team. This communication reduces their total exposure time in the OR and should not limit workflow if the preceding patient will be recovered in the OR by the anesthesiologist (10).

Local policy should include protocols to guide management of patient flows and use of safety measures in the OR. The management of patients with uncertain infective status (e.g. patients under investigation, asymptomatic patients during the peak of a pandemic) should be clearly guided by local protocols during different stages of the

pandemic, to avoid confusion and consequently a risk of 'protocol tiredness'.

Operating Room Preparation

Manipulating the airway during induction and awakening of general anesthesia is associated with aerosol-generation. The anesthesia working space contains numerous surfaces that can harbor droplets thus serving as reservoirs for the virus if proper droplet precautions or proper decontamination processes are not followed (11). Moreover, laparoscopy, pulse lavage and electrocauterization may also lead to aerosolization of blood borne viruses (9, 12, 13).

Laminar flow/Negative pressure room

Several organizations e.g. ASA, ECDC, CDC WHO cite that AGP's should be performed in a negative pressure room (AIIR, airborne infection isolation room), to prevent airborne contamination of surrounding spaces. Negative pressure is created and maintained by a ventilation system that allows extra air to enter the isolated room by differential pressure and be exhausted directly to the outside or be filtered through a high-efficiency particulate air (HEPA) filter directly before recirculation. Negative pressure function for OR's is not universally present in European institutions. The most commonly used OR ventilation systems are Laminar Air Flow (LAF) systems, by which air is supplied in a parallel manner through the OR. This is achieved by providing large volumes of air with a uniform flow field over the clean zone (Fig. 1) (14). The flow can be in a vertical direction (from ceiling to floor) or in a horizontal direction (between walls). The idea is to swipe away or wash out any micro-biological contamination from the surgical zone and prevent bacteria-carrying particles from being encountered in the wound area (15).

The WHO states AGP's should be performed "in an adequately ventilated room – that is, natural ventilation with air flow of at least 160 L/s per patient or in negative-pressure rooms with at least 12 air changes per hour and controlled direction of air flow when using mechanical ventilation." (2).

If a negative pressure setting is not available, it is unclear if LAF should be turned off. This would lower the chance of blowing contaminated air into the surrounding corridor, but at the same time turning off LAF impedes refreshing the air inside of the OR, which holds a potential risk of augmenting surgical site infections. Chinese experience advises

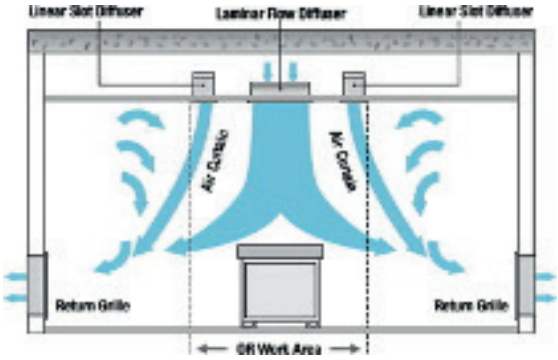

Fig. 1 – Diagram of a Laminar Air Flow system (10).

to switch off positive pressure systems and air conditioning (16, 17). Limiting door openings to the absolute minimum in an OR with LAR turned on is strongly advised (16), especially during and after AGP, allowing enough time for the air inside the OR to be refreshed. Knowledge of the number of air exchanges per hour at your local institution is essential, and the safety period around an AGP should take at least 5 air exchanges to diminish the viral load to <1% of the initial load (9).

Cleaning

Viral pathogen survival on environmental surfaces extends for several days. SARS-CoV-2 can survive for at least 3 days on a variety of materials commonly encountered in the OR (e. g. stainless steel, plastic) in case of a very high viral load. If the viral load is below 10,000 particles, which is closer to reality, the virus persists not more than 5 minutes on any surface (10, 18). Moreover, persistence of virus on a surface does not mean one can be contaminated.

Nevertheless cleaning and disinfection procedures are of paramount importance (with cleaners and water, followed by applying an EPA-registered hospital-grade disinfectant for the indicated contact time). The EPA (US Environmental Protection Agency) website publishes a list on disinfectants registered for use against SARS-CoV-2 (19). This can be extended to other viruses.

Anesthesia ventilator

The anesthesia ventilator is at specific risk for contamination by respiratory viruses, with expired gas returning to the ventilator and re-used in low-flow systems. Internal decontamination of the ventilator system is a difficult process and cannot be readily performed. Therefore all measures should be taken to avoid viral spread inside. A breathing circuit

filter (preferable a heat and moisture exchanging (HME) filter) with a high viral filtration efficiency (VFE) should be used between the Y-piece of the breathing circuit and the endotracheal tube. Moreover installation of a second filter between the expiratory limb of the breathing circuit and the anesthesia machine is advised (16, 20).

A wide range of different filters and producers are on the market and technical details of filters available at your own institution should be reviewed. Almost all mention high bacterial and viral filtration efficiency (at least 99,99%). A VFE of 99.99% means that only one particle in 10,000 (10^4) will pass through the filter under standard test conditions that control flow rate at 30 L/minute. Increased flow rate reduces the VFE (20). It is not exactly known what VFE is needed to prevent passage of SARS-CoV-2 particles from the patient to the anesthesia machine.

There are two main types of filters based on the working mechanism : mechanical (pleated) and electrostatic filters. The term 'High Efficiency Particulate Air' filter (HEPA) is used for filters that remove at least 99.95% (European Standard EN 1822) or 99.97% (US) of particles whose diameter is equal to 0.3 μm, and does not indicate the mechanism of filtration (mechanical or electrostatic).

The diameter of SARS-CoV-2 is around 0,12 mm but transported in droplets or droplet nuclei with a diameter of 1-5 μm.

Both filter types rely to a certain extent on electrostatic charge for their filtering capacity. Electrostatic filters have a low density of fibers and a high charge. Mechanical filters on the other hand consist of a hydrophobic surface with a high density of fibers, which may cause a slightly higher resistance to air flow. Pleating the surface lowers this resistance. The filtration performance of mechanical filters is said to be superior (21, 22) (Fig. 2). They are also slightly more expensive.

An important difference between electrostatic and mechanical filters is their resistance to humidity.

Humidification of air is important during artificial ventilation to maintain mucociliary function. This is particularly important during long-term intensive care ventilation. In the anesthesia setting, humidification is achieved by using low fresh gas flow in a circle breathing system, which consequently allows rebreathing of exhaled air that passes through a CO_2-absorber where water vapor is produced. This ensures for enough humidification during short procedures. For longer surgeries HME filters are positioned at the proximal end of the endotracheal tube (ETT).

Breathing filters can become saturated by condensation liquid from the breathing circuit or by secretions of the patient (especially during prone positioning). This causes a rise in resistance to airflow in the circuit and high-pressure alarms may be activated. Pressure alarms are usually set at 30-40 cmH_2O. Filters should be able to withstand this pressure without passing possibly contaminated liquids from the patient into the breathing circuit or reverse. The German Society of Hospital Hygiene and the German Society for Anaesthesiology and Intensive Care recommend the use of filters that can withstand a pressure of 60 hectopascals (approximately 60 cm H_2O) to allow a margin of safety (23). For electrostatic filters the pressure required to force liquid through is lower than this threshold (23), so possible contamination of the expiratory limb can occur during episodes of high airway pressure. On the contrary, when mechanical filters are obstructed by water, no fluid particles can get through and high breathing circuit pressures will be noted.

In the setting of the highly contagious SARS-CoV-2, the use of a mechanical HEPA filter between the Y-piece and the ETT is consequently advised (11).

To protect the ventilator against the minimal residual (0,01 or 0,001) percentage of viral particles in the expiratory limb, a second filter may be used between the expiratory limb of the breathing circuit and the ventilator itself, to amplify the effectiveness of the HME filter (11). This argument is emphasized in case of electrostatic filter use at the Y-piece due to lack of HEPA filters. This second filter doesn't have to be heat and moisture exchanging (HME).

It should be noted that whilst there has been concern regarding the 0,01 or 0,001% of leakage on the filtering capacity of breathing circuit filters, the respiratory masks of the staff (FFP2 or FFP3) filter 'only' 94% and 99% respectively (Fig. 2). The filters do handle directly expired air from patients, in contrast to the breathing masks of HCW, that filter droplets and 'aerosolized' particles from environmental air.

The necessity of changing breathing circuits between patients is unclear. If a high-quality mechanical breathing filter is installed, soiling of the circuit should be minimal. A study in which the levels of contamination were measured in anesthesia breathing systems used for several patients with an electrostatic filter between the patient and the breathing system ; breathing system contamination was found in 5.6% after 72h (22, 24). Therefore the breathing circuit should be replaced

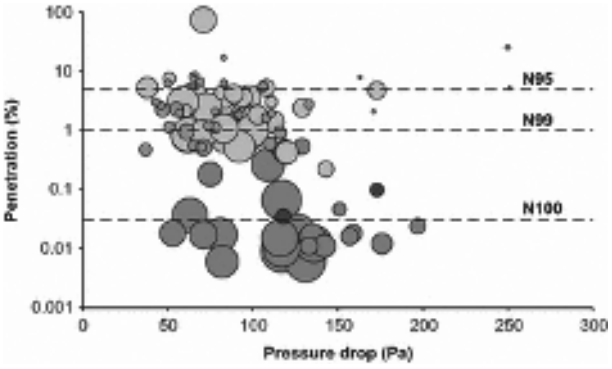

Fig. 2. — Penetration through filters against pressure drop. The size of each 'bubble' is related to the internal volume of the filter. N95, N99 and N100 refer to the three classes of respiratory protective devices when challenged with sodium chloride : N95, better than 95% filtration efficiency (<5% penetration) ; N99, better than 99% efficiency (<1% penetration) ; N100 better than 99.97% efficiency (<0.03% penetration). Adult electrostatic filters : paediatric electrostatic filters ; adult pleated filters ; paediatric pleated filters. All pleated filters were at least N99, no electrostatic filters were N100, some electrostatic filters were not N95 (18).

after every contaminated patient, especially since there is concern of mixture of in- and exhaled air in the Y-piece.

Respiratory gas sampling

Respiratory gas sampling for analysis should be performed after filtering the exhaled air through a high-quality filter (cfr. supra), to prevent viral transmission to the gas analyzer (Fig. 3). Some machines redirect the gas sample for reuse in the breathing circuit, while others direct it to the scavenging system. In the anesthesia setting, directing the analyzed gas to the scavenging system is preferred, in case of reuse in the breathing circuit additional filtering should be present in the water trap. The water trap should be changed before starting non-infected case with this ventilator.

In contrast, when the anesthesia machine is used as an ICU ventilator and scavenging is not present, gas sampling should be disabled or reprogrammed by qualified personnel for redirection to the breathing circuit, to prevent contaminating environmental air. As an alternative, an epidural drug-injection filter can be placed on the gas sample port of the breathing circuit filter before connecting the gas sample line, although this may diminish the quality of the capnograph (20).

Personal protective equipment (PPE)

All personnel involved in the care of a positive patient should wear sufficient protective equipment

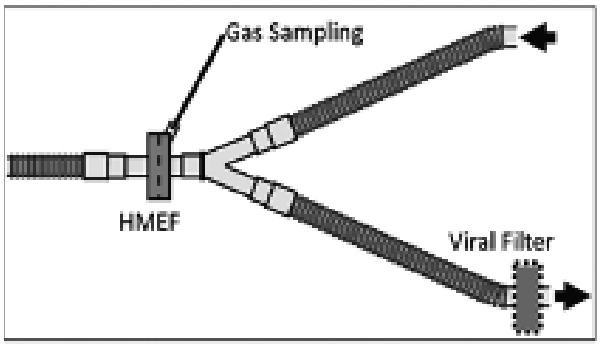

Fig. 3 – Preferred filter and gas sampling configuration (18).

and apply appropriate hand hygiene. National and international guidelines have been published, but practical implementation of PPE differs among centers, due to differences in interpretation and resource. Shortage of supplies during the COVID-19 pandemic obliged further variations. Advises are guided by the mode of transmission in a specific setting, and safety requires protection against the most invasive mode of transmission possible. In the setting of treatment of a COVID-19 positive patient in an OR, this means protective measures should be taken against airborne transmission.

When we look at the guidelines published by the ECDC on PPE for COVID-19 (1, 25), recommendation includes body protection (long sleeved water-resistant gown), mask (filtering face piece FFP3 (N99) or FFP2 (N95) according to European standard 149), eye protection (well fitted goggles or face shield) and gloves.

Concerning the FFP masks ECDC recommends always using an FFP3 for aerosol generating procedures, as FFP3's filtering capacity for airborne particles is 99%, in comparison to 94% for FFP2 (1). WHO states using an FFP2 (2). The confusion on this topic rose dramatically when several centers reported test results revealing insufficient filtering capacity of newly delivered masks during the COVID-19 pandemic, despite recording FFP2 on the technical details.

FFP2 or FFP3 masks do not fit each face morphology. HCW need to be aware of the fact that these masks can be totally useless if not adequately adapted. A quantitative face fit test before clinical use is advisable.

During surgery, when the airway is protected by an ETT and no AGP takes place, a surgical mask is probably sufficient, but to avoid confusion it may be safer to keep wearing the FFP2.

The ECDC defines body protection as a long-sleeved impermeable gown, referring to its technical guidance document on PPE for treatment

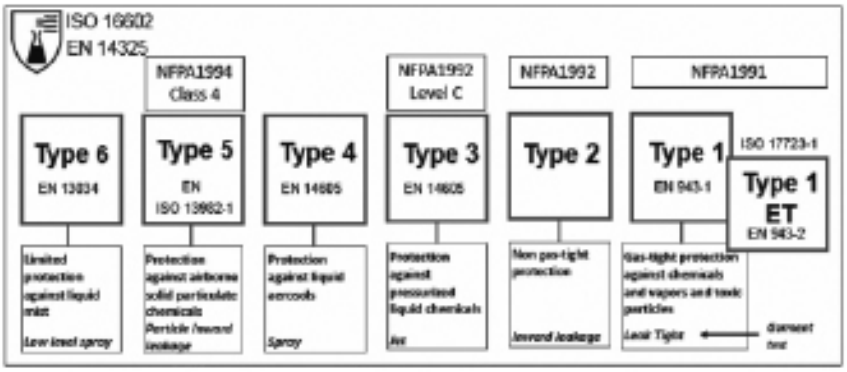

Fig. 4. — Overview of different global standards (EN: European Norm, ISO : International Organization for Standardization, NFPA : National Fire Protection Association) (24).

of 'Infectious Diseases of High Consequence' (IDHC). This states that a coverall is preferred, which makes it debatable. Probably the importance of the material of the body protection outweighs the choice between gown of coverall, as both have pro and cons. Coveralls implicitly cover more body parts, including head, neck and lower legs, but are more difficult for doffing without the risk of self-contamination. WHO explicitly states that a coverall is not necessary (2).

The quality norms on protective clothing are difficult to interpret as different classifications exist (26, 27). Protective clothing in medical settings should mention the European quality Norm (EN) 14126, which indicates appropriateness to protect against biohazards (air- or bloodborne infective agents). Functional details, such as taped seams, attached hoods, or covered zippers are not defined by EN 14126. Therefore, these specifications need to be checked and specified.

Reference to the classifications used in chemical industry (EN14325 and ISO 16602) is often mentioned, which grades leak tightness to chemical exposure in 6 Types (Fig. 4).

The addition of the letter 'B' to the Type (e.g. Type 5-B) indicates that the material is certified for biological contaminants according to EN 14126. This can also be indicated by the pictogram in Fig. 5.

The ECDC states that fabric of class 3B is good for working with IDHC.

The label 'Category III' implies annual third party confirmation of the certificate validity, which is mandatory for protection against dangers that seriously harm health.

EN 14126 comprises several testing methods for permeation of different biological substances. These can be separately indicated, and are graded, with the highest class indicating the best protection,

Fig. 5. — EN14126 Protection against biohazards.

Table 1

EN 14126 testing methods for permeation of biological substances

ISO 22610	microbial permeation of liquids	grade 1-6
ISO 22611	microbial permeation of aerosol	grade 1-3
ISO 22612	microbial permeation in dry conditions	grade 1-3
ISO 16603	pressure needed for permeation of blood borne pathogens and synthetic blood	grade 1-6
ISO 16604	pressure needed for permeation of blood borne viruses	grade 1-6

e.g. ISO 16604 grades the protection against blood borne viruses. (Table 1)

In the operative setting surgical sterile gowns are also required. Due to the shortage of protective clothing during the COVID-19 pandemic, surgical gowns also could be used outside the OR, on the COVID-19 wards. Those gowns are certified by a different norm EN 13795, which focusses on the protection of the patient, in contrast to the before mentioned EN 14126 which implicates protection of the medical staff, thus the direction in which the sample is brought into contact with the contaminating agent during the test is opposite. Although making comparison difficult this doesn't mean surgical gowns are less protective.

EN13795 mostly doesn't mention testing method ISO 16604 for viral penetration. Surgeons wonder if it is necessary to wear a protective gown

under the surgical sterile gown. If the sterile surgical gown is adequately reinforced or fluid resistant, wearing a protective gown underneath is probably not necessary. The WHO states that aprons should be used if gowns are not fluid resistant (2).

The US hands a different classification (AAMI : Association for the Advancement of Medical Instrumentation) for medical protective apparel as well as for surgical gowns. For protection against viral penetration, the highest AAMI level 4 (test ASTM F1671) is required.

During the COVID-19 pandemic a world-wide concern was expressed on shortages of adequate PPE for healthcare workers. Because of this pressing shortage engineers started to design and produce alternatives. E.g. the 3D printing of an adaptor to connect a HEPA filter to the re-usable water-sealing Decathlon Easybreath Subea diving mask, as an alternative to an FFP2 mask for protection of HCW (Fig. 6). Keeping in mind the different filtering capacities of FFP2 and HEPA filters, this may even be a superior alternative. This system hasn't been biomedically certified as concerns are expressed that the water-sealing capacity of these masks depends partially on external pressure caused by the water during diving, and due to the necessity of closing the water purge valve of the mask before use as a filtering face piece.

This text describes the ideal technical details of PPE components, but reality obliges to accept that these high standards may not always be fulfilled.

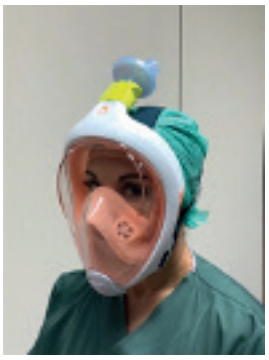

Fig. 6. — Experimental face guard. Adaptor for Decathlon Easybreath Subea mask designed by A. De Beir,, PhD Faculty of Engineering Vrije Universiteit Brussel ICW. Dr. B. Geniets MD, GZA Ziekenhuizen.

Aerosol generating procedures in the operating room

Aerosol generating procedures (AGPs) include endotracheal intubation and extubation, bronchoscopy, open suctioning, manual ventilation before intubation, disconnecting the patient from the ventilator (or actions with augmented risk on disconnection e.g. physical proning of the patient), tracheostomy, and cardiopulmonary resuscitation. For some procedures there are conflicting data on whether they have to be regarded as infectious aerosol generating or not, e.g. administration of nebulized treatment and high-flow nasal oxygen (3, 9, 17, 28).

Also certain surgical procedures carry a risk on aerosolization of respiratory virusses, e.g. thoracotomy and pneumothorax exsufflation. The air evacuated from the pneumoperitoneum during or after laparoscopy can also lead to aerosolization of blood borne viruses (13). No clear evidence exists on the risk of laparoscopy in COVID-19 patients, but care should be taken and laparoscopy should only be performed when strictly indicated. The Society of American Gastrointestinal and Endoscopic Surgeons has published practical safety measures on laparoscopy, surgical indications and electro-cauterization (12).

As AGPs are increasingly being recognized as an important source for nosocomial transmission of emerging respiratory viruses, protection measures are required (5). During the SARS outbreak, intubation was one of the independent risk factors for super-spreading nosocomial outbreaks affecting many healthcare workers in Hong Kong and Guangzhou, China (28).

Personal protective equipment should be used as mentioned above : a non-sterile long-sleeved gown with adequate quality norm, FFP2 (N95) masks or equivalent, eye protection (face shield or well fitted goggles) and gloves, preferably a double pair of gloves, well covering the wrists. A surgical hat is also recommended and is usually worn in the OR. After the procedure at least gloves and if stock allows also the gown are switched and appropriate hand hygiene is applied, before moving on with the surgery.

If there is a shortage of FFP2 (N95) masks or other PPE components it is recommended that they are prioritized for AGPs. To preserve supplies and contamination risk, the number of persons present in the room during AGP's should be limited to the absolute minimum required for the patient's care and support.

Intubation / Extubation

Several instructions on intubation and extubation of COVID-19 patients have been published and all are fairly similar (2, 3, 11, 16, 19, 29, 30). In

the setting of the operating room, intubations will be mostly (semi-)elective and permit adequate planning and preparation of safety measures, according to the same guidelines. ICU patients on high flow nasal oxygen or non-invasive ventilation needing surgery may be best intubated before transfer to the OR.

Standard monitoring, intravenous access, instruments, drugs, ventilator, and suction should be prechecked. Rapid sequence induction (RSI) is advised, with 3 minutes of preoxygenation with 100% oxygen (31). Pre-oxygenation can be performed with a Bag Valve Mask device with positive end expiratory valve and a viral filter, if available. It is recommended to keep a good facemask seal with both hands, while making sure not to deliver any positive breaths. Wet gauze can be put around the mouth and nose to block secretions (16). The utilization of a high flow nasal canula (HFNC) in the ICU does not increase either dispersion or microbiological contamination into the environment when compared to oxygen therapy with a mask. The patient being able to wear a surgical mask on top of HFNC, in order to reduce the aerosol transmission during coughing or sneezing, represents an additional benefit (32). The use of HFNC is rarely applied in the OR and to date there are no publications of its use in contaminated patients prior to induction. If possible, it seems more appropriate to avoid HFNC in the OR considering the face mask for induction has better sealing capacities. Induction and relaxant medications should be administered at a sufficient dose in order to prevent cough or gag reflex during the procedure (29, 30). RSI may need to be modified if the patient has very high alveolar–arterial gradient and is unable to tolerate 30 seconds of apnea or has a contraindication to a neuromuscular-blocking drug. If manual ventilation is required, small tidal volumes with low pressure should be applied. The intubation technique which can reduce the number of attempts at endotracheal intubation, the duration of the procedure and the proximity between the operator and the patient, should be prioritized. Therefore the use of video-guided laryngoscopy is suggested over direct laryngoscopy, if available. Moreover, the endotracheal intubation should be performed by the healthcare worker who is most experienced with airway management. In a failed airway scenario, attempts should be made to establish a surgical airway immediately. Avoid awake fiberoptic intubation unless specifically indicated.

Connecting the HEPA-filter on the ETT before insertion is advisable to prevent contamination in case of coughing after insertion.

The ETT should be positioned at a predetermined depth and secured properly. No breaths should be delivered until the cuff is inflated. Avoid auscultation attempts to prevent instrument contamination, instead assessing for bilateral chest rise and end-tidal capnography waveform.

A plastic transparent sheet can be placed over the patient's head and chest during the procedure to prevent droplet spread, although this may limit visibility and may be difficult to dispose without contact transmission.

All contaminated instruments should be placed in a bag for immediate disposal and/or decontamination.

As RSI is always applied when performing emergency intubation, the same measures as stated above are advised when an emergency intubation is necessary in a contaminated patient.

Cough is a common event following premedication with an opioid such as fentanyl (given prior to induction of anesthesia) and can be prevented by a single intravenous dose of lidocaine (0.5 mg/kg) (33). In addition, coughing and bucking are also prevalent events during extubation. Therefore also during extubation a plastic transparent sheet can be placed over the patient's head and chest. Full PPE should be worn by the HCW and the patient's face mask should be kept close so that it can be put on shortly after extubation. Usage of endotracheal aspiration needs to performed with a closed system.

Emergence coughing is a challenging issue and a variety of medications have been proposed to prevent it. Administration of intravenous lidocaine (which is readily available) prior to tracheal extubation can effectively reduce emergence coughing (34). Also dexmedetomidine (0,5-1 µg/kg IV) is being put forward to prevent emergence coughing and appears to be effective (35).

Regional or general anesthesia

To diminish the number of aerosol generating procedures, the use of neuraxial anesthesia and peripheral nerve blocks is preferred in infected patients whenever possible, as stated by a Joint Statement of the American and European Societies of Regional Anesthesia and Pain Medicine (36, 37). Critical minds point to the risk of the coughing patient, but the odds of transmitting a respiratory infection to a HCW during tracheal intubation is 6.6 times compared to those who are not exposed to tracheal intubation (28). Patients should wear a surgical mask and if oxygen supplementation is

required, the oxygen mask can be put over or under the surgical mask.

Moreover, regional anesthesia has less impact on the patient's respiratory function, which is specifically important in symptomatic patients or patients with confirmed abnormalities on thoracic CT. For upper limb surgery the option with the least respiratory consequence should be chosen, such as an axillary block, or infraclavicular block. Normal precautions and contra-indications should be taken into account before performing the block. It is advisable to exclude thrombocytopenia in COVID-19 positive patients. The Obstetric Anesthetists' Association suggests outweighing risk-benefit in febrile patients (38), in truly septic patients neuraxial block is always contraindicated. Vigilance for hypotension during neuraxial block is recommended (36, 37).

Placing a nerve block should always be performed by the most experienced clinician, inside the dedicated OR, after taking all precautions on PPE. FFP2 masks are preferred over surgical masks (7, 11), although performing regional anesthesia is not considered an AGP conversion to general anesthesia (GA) is. All necessary medication should be prepared outside in advance, and the ultrasound machine should be adequately protected with a plastic cover and probe sheet. The advantage of perineural adjuncts should, as always, be balanced against the risks. No clear recommendations on this topic are present until now. Adequacy of the block should be tested thoroughly before proceeding to surgery, to avoid the need for sedation or unplanned conversion to GA. If the complexity of the surgery means a high probability the procedure cannot be entirely performed under regional anesthesia, it is better to start with GA anyway. Additional analgesic blocks during GA may be helpful in reducing PONV risk and opioid requirements and thus respiratory consequences postoperatively. Nevertheless, it is not recommended to reposition the patient for an additional block, as this imposes a risk of disconnection of the ETT (36).

Preoperative testing

In case of a positive patient presenting for surgery, local guidelines are usually clear. The surgery is performed in the dedicated OR and all staff is aware all available protective measures should be taken.

Confusion starts when other patients present for surgery. During the COVID-19 pandemic elective cases have been postponed in most institutions to create space on wards and the ICU, reduce resource demands and to allow relocation of OR staff to services where help is needed. However, clinicians have to decide whether it is justified to perform urgent cases. The American College of Surgeons presents an extensive list for guidance on triage decision making (39).

As the operative setting presents a high risk of contamination and transmission, ideally the viral status of all surgical patients should be known. Unfortunately the PCR laboratory capacity in many institutions cannot facilitate routine testing at this time. Moreover, PCR testing of SARS-CoV-2 on respiratory specimens (nasopharyngeal swab or sputum) has a significant number of false negative results of up to 29%, depending on time of testing since symptom onset and quality of the sampling (40, 41).

Institutional guidelines for preoperative PCR testing can be based on clinical presentation. The surgeon is responsible for taking a risk history before planning. A PCR test should at least be performed if the patient has a suspicious history (e.g. in case of COVID-19 fever, cough, sore throat, myalgia, chest tightness, anosmia, ageusia or living with a COVID-19 positive housemate) If the degree of urgency doesn't allow delay until PCR results are present, the patient should be treated as 'Patient Under Investigation' (PUI), and all measures should be taken as for the COVID-19 positive patient with the surgery taking place in the dedicated COVID-OR. Rapid antigen tests are available but are less sensitive than PCR. A negative antigen test should always be followed by a PCR. Thoracic CT or lung ultrasound may provide useful information, although findings are not specific and routine use for diagnosis is not recommended (42, 43). The high number of false negative PCR results has important implications on transmission risk and in case of clinical suspicion thoracic CT and a new PCR test after 24 to 48 hours should be performed, if possible on a lower respiratory tract specimen.

Considering the extent of contamination in society, the possibility of transmission through asymptomatic patients and the number of false negative PCR, ideally all AGP's, even if there is no clinical suspicion, should be considered as possibly contaminating (11, 36), although not performed in the dedicated OR. The Anesthesia Patient Safety Foundation recommends escalation of protection during all AGP (gown, FFP2 or FFP3 mask, goggles or face shield, double gloving). Consequently this poses a pressure on the already limited availability of PPE. For non-suspicious patients, treated in a non-

dedicated OR, it would be advisable to remove the gown after finishing AGP to prevent contaminating trays and cupboards. Besides that, the number of staff involved during AGP should be limited for every case and filters used to protect the anesthesia ventilator from contamination.

Conclusion

Respiratory pathogens, like SARS-CoV-2, are primarily transmitted through contact and droplet contamination, but prudent attitude implicates prevention of possible airborne transmission as well, mostly by AGP. Surgery on infected patients should be performed in a dedicated OR, and airflow contamination of surrounding rooms or corridors should be prevented. Careful OR management can limit number of involved personnel and isolate pathways from non-infected patients. The anesthesia ventilator should be protected with a mechanical HEPA breathing circuit filter on the Y-piece, and a second filter with high VFE on the expiratory limb is advisable. One of these should be HME during long procedures. Direction of gas sampling flow through the ventilator should be known and if possible scavenged. FFP2 respirator masks or equivalent should be worn at least during all AGP, as well as a long-sleeved impermeable gown of standardized quality, eye protection, gloves and a surgical hat. Intubation and extubation should be performed following a strict protocol and the number of persons involved should be limited. When possible, regional anesthesia is preferable. During a pandemic all patients should be regarded possibly infective, and local policies should include additional safety measures for all patients.

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