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Operative team checklist for aerosol generating procedures to minimise exposure of healthcare workers to SARS-CoV-2

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ABSTRACT

Objectives: In many countries around the world, the COVID-19 pandemic has resulted in health services being diverted to manage patients with the condition. There are situations however that still require the undertaking of aerosol generating procedures (AGP) with potentially high exposure of healthcare workers to SARS-CoV-2 transmission through droplet, contact and possibly airborne routes. The objective of this paper is to explore a structured way for the operative team to approach AGP to reduce aerosolisation of secretions, decrease open airway time and minimise staff exposure.

Methods: The authors (otolaryngologists, anaesthetists and nursing staff) created a unified operative team checklist based on collation of national and international specialty society statements, local state government recommendations, hospital policies and literature review. Simulation was undertaken and the checklist was refined after performing AGP on patients with unknown (presumed positive) COVID-19 status.

Results: An 8 step operative team checklist is provided describing details for the immediate pre-operative, intra-operative and post-operative journey of the patient to encourage healthcare workers to reflect upon and modify usual practice during AGP to mitigate exposure to SARS-CoV-2. The example of paediatric laryngo-bronchoscopy for diagnostic purposes or retrieval of an inhaled airway foreign body is used to illustrate the steps however the checklist structure is modifiable for other AGP and adaptable for local needs.

Conclusions: At a time of overwhelming and changing information and recommendations, an operative team checklist may provide some structure to healthcare workers undertaking AGP to reduce anxiety, maintain focus, prompt consideration of alternatives and potentially reduce risk.

1. Introduction

The World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) caused by the virus SARS-CoV-2, a pandemic on March 11, 2020 [1]. Droplet inhalation into the respiratory tract and contact transmission through infected secretions are thought to be the chief routes of person to person transmission [2]. The potential for airborne transmission is still being studied [3–6], and if proven, will have a major impact on measures to reduce transmission as well as the need and use of personal protective equipment (PPE) [7–10]. Patient respiratory activity and medical procedures such as intubation, bronchoscopy or respiratory tract suctioning are thought to generate aerosols that may remain airborne for some time and place healthcare

workers at risk of infection. Otolaryngologists and anaesthetists in particular, perform these high-risk aerosol generating procedures (AGP) which expose them to potential droplet, contact and airborne transmission of SARS-CoV-2 [5,8,10–13], whether the patient is in a symptomatic or asymptomatic phase of the disease process.

As the case numbers of COVID-19 have grown exponentially around the world, elective surgical operations have been reduced in many centres to allow diversion of resources to areas of need such as intensive care units. There are circumstances however in which AGP still need to be performed. In preparation for undertaking these procedures as safely as possible, there has been an overwhelming amount of information to absorb from the growing literature, medical society statements, governmental recommendations, hospital infection control and local

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department policies, as well as news feeds and social media exchanges between health professionals.

The situation is changing daily, resulting in generalised heightened anxiety among healthcare workers about access to appropriate PPE [7,10] or powered air-purifying respirators (PAPR) [10,11], and how to modify protocols for AGP from usual practice to minimise risk. During this pandemic, some paediatric services have been taken over by adult patients and staff have needed to be deployed to areas they have had minimal training in. Infected healthcare workers can affect departmental rostering such that AGP may need to be undertaken by clinicians who are less accustomed to the procedure in normal circumstances. Emergencies requiring AGP may need attendance after hours and working with unfamiliar staff with variable skillsets and knowledge of the risks.

For all of these reasons, a concise and unified operative team checklist detailing the principles of patient flow can be helpful for staff involved with AGP to consider and follow. Approaching AGP during this crisis requires a shift in mindset of the whole team involved, moving away from productivity and turnover to, instead, emphasising safety and risk mitigation. This requires actively taking time to pause and contemplate instances when respiratory secretions could be aerosolised and the area where they might linger, protective measures to avoid droplet inhalation and contact with contaminated surfaces, and alteration of techniques to minimise routes of transmission to healthcare workers. Surgeons and anaesthetists need to be proactive in balancing safe patient management with protection not only of themselves, but their trainees, nursing and operating theatre staff.

A checklist can provide a practical framework for the immediate pre-operative, intra-operative and post-operative needs of the participating teams and can be modified to suit individual preferences, procedures, hospital layout and practices. Breaking down the steps into manageable, practical components that can be printed onto a couple of pages and ticked off, rather than multi-page documents from several stakeholder departments and authorities, may reduce the intimidation of undertaking AGP during the COVID-19 pandemic.

2. Materials and methods

The authors work at a tertiary children's hospital that is co-located with a tertiary adult's and women's hospital with a neonatal intensive care unit. The operating theatre complex is shared between the hospitals with designated theatres for adults, children and the women's hospital, though there can be crossover use of the facilities if needed. All authors are experienced in Otolaryngology procedures especially those involving aerosol generation.

In preparation for performing AGP on patients positive for COVID-19 or whose status is unknown and treated as potentially positive, the authors collated information from Australian and international society statements [14–18], WHO publications [8], local state health department recommendations, hospital department policies, and reviewed the emerging literature [5,10–12,19–23]. Three AGP were undertaken prior to the formulation of the operative team checklist. Simulation was performed with a mannequin in the operating theatre using the example of paediatric laryngo-bronchoscopy for retrieval of an airway foreign body. Amendments to the checklist were made after performing 14 various high-risk Otolaryngology AGP on paediatric and adult patients with unknown COVID-19 status (presumed positive). One of these cases was the emergency removal of a pistachio nut from a distal left main bronchus on a 16-month old child weighing 10.7 kg that had been inhaled 6 days prior to presentation (Fig. 1). The child was COVID-19 negative but managed as status unknown with full high-risk AGP precautions to allow real life simulation and identification of areas for improvement.

A unified checklist was created to incorporate the perspectives of all the teams involved. Details were included as reminders for staff less acquainted with the nuances of the modifications to be made for AGP.



Fig. 1. Clinical photograph during airway foreign body removal in a 16-month old child. The surgical team were wearing PAPR however the anaesthetic team had elected not to as the child was COVID-19 negative and they had not completed training in PAPR use prior to the emergency procedure.

The design was intended to be adaptable such that equipment or considerations for other high-risk AGP (e.g. tracheostomy, endoscopic sinus surgery) could be easily substituted, and updates made as further evidence unfolds and practices are refined.

3. Results

The following 8 steps and the general principles behind it are proposed to assist surgeons, anaesthetists, nursing and operating room staff in the management of patients requiring AGP during the pandemic of SARS-CoV-2 to minimise their exposure (Figs. 2 and 3). The example of paediatric laryngo-bronchoscopy for diagnostic purposes or removal of inhaled foreign body is used to illustrate some of the steps with a sample provided of the checklist from our institution (Fig. 4). The detail included here is to highlight the process rationale and can be abbreviated once staff are trained and familiar with the routine.

Overview of operative team checklist for high-risk AGP

1. Notify operating theatre front desk and duty anaesthetist
2. Full team huddle led by senior anaesthetist
 - a. Communicate clinical information
 - b. Communicate specific concerns (including times of aerosol generation)
 - c. Confirm general anaesthesia plan and surgical plan
 - d. Confirm positioning
 - e. Confirm equipment required inside the operating theatre
 - f. Confirm equipment required immediately outside the operating theatre
3. Equipment and staff preparation
4. Patient retrieval and arrival
5. Procedure commencement
6. Aerosol generating procedure
7. Procedure completion
8. Surgical and anaesthetic staff stand down

Fig. 2. Summary of 8 step operative team checklist used for high-risk aerosol generating procedures (AGP).

General principles of approach for high-risk AGP

- Take time to plan and communicate modifications to usual approach
- Use highest level of personal protective equipment available (after adequate training)
- Involve the fewest number of staff to safely perform the procedure
- Restrict operating theatre access once patient has entered the room
- Limit direct patient contact as much as possible
- Employ the least aerosol generating techniques and reduce open airway time
- Minimise handling of contaminated instruments and surfaces where respiratory secretions may have settled

Fig. 3. The general principles of approach for high-risk aerosol generating procedures (AGP) used to develop the operative team checklist.

3.1. Notify surgical booking centre and duty anaesthetist

Depending on the patient's condition, it is preferable to perform AGP during daytime working hours. A designated COVID-19 or on call anaesthetic team may need to be activated to attend. A pre-operative anaesthetic assessment should include the need for pre-medication and local anaesthesia cream application, as well as timing of administration for a child. The surgical team is responsible for ensuring that all relevant results are available, as well as consent paperwork including consent for collection of intra-operative swab for COVID-19 testing if status is unknown. Specific operating theatres should be allocated for treating these patients, preferably in a negative pressure room with separate access to the main theatre block entrance. If the layout of the operating complex dictates that the room is in a thoroughfare area, signs or barriers should be erected to notify staff that a high-risk patient is attending and to avoid unnecessary passage through that area.

3.2. Full team huddle

One of the most important steps of the checklist is the full team huddle prior to commencement of AGP. The senior anaesthetist is the assigned team leader. All team members (surgical, anaesthesia, nursing, assistants, and recovery staff) should be present at this huddle, introductions made and roles defined. Staff are reminded to cross monitor each other for potential contamination during every phase of the patient encounter.

The designated COVID-19 operating theatre should be stripped of all unnecessary equipment to reduce contamination of their surfaces. Performing the full team huddle in the allocated room is useful to prepare for positioning requirements especially in a shared airway case. Patience is required by everyone involved as the preparation for AGP can take much longer than the procedure itself. Given that there may be no patient files or computers to access records, a whiteboard on the wall can be helpful to document the patient name, medical record number, weight, allergies, procedure, specific site or side, and staff present in the room.

In our institution there may be two anaesthetists allocated (one "contaminated" to manage the airway and the other "clean" focused on anaesthesia delivery), an anaesthetic nurse in the operating theatre and a clean anaesthetic runner outside, one surgeon and a surgical assistant, one scrub nurse and one scout nurse in the room, a clean scout runner outside, and an operating assistant (orderly) outside the room allocated for patient handling and transfers. A second clean operating assistant who does not touch the patient may be required to assist with clearing the corridors and lift access during patient transport however if not available, the clean anaesthetic room runner may take that role. It can be useful to have a surgical trainee assisting the clean scout runner outside the theatre to efficiently identify equipment needing to be passed in. A different coloured impervious gown worn by the outside clean runners has been beneficial as a visual indicator of their status compared to the inside team.

The full team huddle should include communication about the following details elaborated in 3.2.1 to 3.2.6.

3.2.1. Communicate clinical information

Essential information from the surgical team should include the patient's age, COVID-19 status and risk profile, procedure indication, relevant clinical background and investigations, fasting time and anticipated need for PPE versus PAPR if available. In our institution, PAPR (sterilised through the Central Sterile Services Department) is available though not mandated for all participating staff. Prior training in its use, donning and doffing is required and the surgical team will not perform high-risk AGP for high-risk patients without it. Relevant clinical imaging may need to be printed to have available in the operating theatre though will be disposed of at the end of the case.

3.2.2. Communicate specific concerns

Specific concerns should be acknowledged such as highlighting the times when aerosol generation is anticipated to be greatest, patient in extremis, known difficult airway, extreme obesity, and difficult intravenous access or drug/anaesthetic allergies.

3.2.3. Confirm general anaesthesia and surgical plan

The senior surgeon and anaesthetist should communicate their preferred techniques for general anaesthesia delivery and surgical plan, with back-up plans discussed. Both teams need to be flexible and open to considering alternative techniques balancing the goals for the AGP with the risks of droplet and contact transmission, secretion aerosolisation, and doing no harm to the patient. The use of the microscope might be deemed impractical or not feasible due to the use of PAPR and a telescopic assessment may need to suffice. If a therapeutic intervention is indicated, cold steel techniques are preferred over powered instrumentation. Diathermy and laser modalities are avoided if possible due to the generation of plume. Haemostasis is obtained through the use of topical agents (e.g. 1:10,000 adrenaline or oxymetazoline) applied on neuropathies.

In the case of a paediatric patient, the caregiver may or may not be allowed to escort the child to the operating theatre complex and anticipated pre-medication timing or transport issues to the designated entrance should be considered. In our institution, the child's caregiver (who is presumed to be the same COVID-19 status as their child unless proven otherwise) does not accompany them to reduce the number of people involved and to maintain distancing from the operative team. The anaesthetic team is responsible for notifying the patient's location of the plan and any ancillary items needed to accompany the patient such as essential photocopied paperwork and paediatric surgical masks.

For laryngo-bronchoscopy, the pros and cons of spontaneous ventilation versus apnoeic techniques should be evaluated depending on the indication for surgery, patient condition, individual preference and experience. Trying new techniques under circumstances of heightened staff anxiety may not be as safe or efficient as usual practice and may risk prolonging surgery or introducing unnecessary rescue measures. Modes of general anaesthesia delivery should be decided upon, including the need for suitable adaptors or connectors. Attempts to use closed suctioning and ventilating systems are advised if practical and available.

The use of topical local anaesthesia, amount, type and who is going

ENT – Aerosol generating procedure checklist for Sydney Children’s Hospital

(Includes diagnostic laryngo-bronchoscopy, intubation assistance, FB retrieval from airway or oesophagus)

1. **NOTIFY FRONT DESK & DUTY ANAESTHETIST** – patient details, location, procedure, urgency, prefer daytime, consent
2. **FULL TEAM HUDDLE and document on whiteboard patient name, MRN, procedure, site/site, allergies, weight, staff:**
 - 1) Anaesthetist x 2 (clean & airway), anaesthetic nurses x 2 (one inside, clean runner in yellow gown)
 - 2) Surgeon and assistant, surgical nurses x 3 (scrub, scout, clean runner in yellow gown)
 - 3) Operating assistant x 2 (for patient handling, for clearing corridors and assisting transport in & out)
 - a. **Communicate clinical information:** indication, patient background, COVID status, fasting time, PPE/PAPR
Print out relevant clinical imaging or essential records if needed in theatre (discarded at end of case)
 - b. **Communicate specific concerns:** e.g. times of aerosol generation, difficult airway/IV access, obese, allergies
 - c. **Confirm GA plan and surgical plan** – preferred techniques as well as backup plan suitable for clinical indication
 - 1) Premedication, EMLA, caregiver site, transport - notify patient location of plan and items to bring
 - 2) GA technique – spontaneous ventilation, apnoea, anticholinergic, TIVA, dexmedetomidine, \pm steroids
 - 3) GA delivery –mask, LMA, ETT (type/cuffed/uncuffed/sizes needed) and adaptors for bronchoscope
 - 4) LA delivery, amount and type –disposable MADgic device with tip trimmed and luer lock syringe
 - 5) Intra-operative and post-operative plan including recovery location and transfer destination
 - d. **Confirm positioning**
Operating table, IV stand, shoulder roll/head ring, staff, warmer, equipment, box/side arm/Mayo, bins, suction
 - e. **Confirm surgical equipment for laryngo-broncho-oesophagoscopy inside the operating theatre**
 - 1) Image capture system, dual LED light source, adequate power boards, operating stool
 - 2) LBO trays, 4mm and 2.7mm Hopkins rod, light leads and camera, bridge to create a seal
 - 3) Appropriate sized rigid bronchoscope +/- oesophagoscope, plus immediate size smaller, corrugated connector “liquorice stick” to connect to ventilating bronchoscope
 - 4) Storz flexible suction catheter to fit down working channel of rigid bronchoscope (closed system)
 - 5) 3mL luer lock syringe for topical therapy via Storz flexible catheter (or 5Fr NGT, 10ml purple syringe)
 - 6) Nasal packing set, small neuropatties, 3mL syringe, oxymetazoline to reduce nasal secretions
 - 7) 0.5% Povidone iodine preparation – 1ml betadine 10% diluted with 19 mL sterile water
 - 8) Long forceps and Raytec x 5 – available for topical povidone iodine application in oral cavity
 - 9) Medications: 1:10,000 adrenaline, 3mL syringe (for topical use if granulation or bleeding)
 - 10) Appropriate sized ETT to have as rescue (plus size above and below) and baby McGill forceps, discuss with anaesthetist whether to have cuffed or uncuffed tube depending on patient’s pathology
 - 11) Perspex box, side arm, plastic drape x 2 (torso, over face), blue sheet (head), extra suction, drape tape
 - 12) Microbiology swab for COVID-19 test collection
 - f. **Confirm potential spare instruments and consumables immediately outside the operating theatre**
 - 1) Spare 4mm and 2.7mm 0 degree scope, 30 degree scope, 1.9mm scope, camera, light lead
 - 2) Spare rigid bronchoscope and oesophagoscope in various sizes
 - 3) AMBU disposable bronchoscope and viewing device (consider plastic cover) – size 3.8mm or 5.0 mm
 - 4) Self-sealing suctioning elbow for flexible bronchoscopy (code 66-1991P)
 - 5) Foreign body set, optical graspers and 2.9 mm long telescope, non-optical peanut and other graspers
 - 6) Laryngoscopy micro-cupped forceps (+/- micro-scissors)
 - 7) Oesophagoscopy graspers if oesophageal foreign body
 - 8) Flexible endoscopy forceps (1.9 or 2.8mm) -smaller fits through 5.0 AMBU channel or rigid scope port
 - 9) Medications: cophenylcaine, steroids (depending on case), extra anti-fog, warmed water for scope
3. **EQUIPMENT AND STAFF PREPARATION (anaesthetic and surgical)**
 - a. Individual surgical and anaesthetic team huddles to confirm own plans, prepare equipment/drugs/infusions
 - b. Staff welfare – nutrition, hydration, use bathroom, remove personal devices, arrange back up on call available
 - c. Enter patient details into image capture system
 - d. Request form for COVID swab or any other pathology printed and patient labels prepared
 - e. Check intercom system, agreed signal for attention, portable whiteboard to communicate to outside runner
 - f. Name/role tags on balaclava (hard to differentiate staff in PPE or PAPR) – use blank patient adhesive labels
 - g. Donning of PPE/PAPR as per flowsheet (if using PAPR register headpiece number for contact tracing)
 - h. All instruments opened and connected to tower, white balance/focus done to minimise time wastage
 - i. Check suction, foreign body forceps fit through instruments, check ETT & rigid bronchoscope fit Parson’s slot
 - j. Instrument trolley moved next to tower for patient bed entry into theatre, surgical suction left disconnected

Fig. 4. The ENT checklist used at Sydney Children's Hospital for aerosol generating procedures is provided as an example detailing site-specific nomenclature, equipment and preferences. Numbered point form was used, and the font and margins of the layout were adjusted to allow printing on only 2 sheets of paper to be less overwhelming at a time of information overload.

to deliver it should be clarified. If using, the mode of administration onto the larynx should be slow and deliberate (e.g. droplet delivered through a blunt catheter), avoiding atomisation and potential spray back towards the operator. Systemic agents to reduce upper airway secretions or topical nasal decongestants (applied on a pledget or slowly dripped in via a syringe rather than sprayed) can be of benefit in some

circumstances. Systemic steroids to reduce airway inflammation may need to be clarified depending on the patient's pathology and the latest evidence based recommendations for a known COVID-19 positive patient. The role of preparing the nasal and oral cavity with a 0.5% solution of povidone iodine on pledgets for its virocidal properties towards SARS-CoV-2 is unknown at this point in time [24–27] but is

4. **PATIENT RETRIEVAL AND ARRIVAL (by anaesthetic team and operating assistant)**
 - a. Anaesthetic and scrub team confirm readiness prior to retrieval, ward/ICU notified to prepare patient
 - b. Patient to wear a surgical mask for transport if tolerated, no parent escort allowed
 - c. Phone call to update theatre staff when leaving the ward to confirm patient is en route
 - d. Surgical check in at theatre door (NB. only pre-op checklist, photocopied consent and front sheet will accompany patient; patient adhesive labels will be printed in theatre and unused ones discarded)
 - e. Patient brought directly into operating room bypassing anaesthetic bay for team time out
 - f. Doors are closed and no exit from the theatre once the patient has arrived

5. **PROCEDURE COMMENCEMENT**
 - a. All staff to cross monitor team members for potential contamination
 - b. Staff to stay distanced from head of patient as much as possible until required to approach
 - c. Speak loudly when wearing PPE/PAPR, preferably one at a time or use designated hand gesture for attention
 - d. Blue sheet under head, chest exposed, plastic on torso, perspex box/side arm/Mayo table, 2nd large plastic over patient & instruments taped down free edges, suction from patient's feet end taped to right side mouth
 - e. Mask to seal (2 handed technique), 100% oxygen and sevoflurane induction, establishment of IV access
 - f. Option to place LMA or intubate depending on indication for surgery, closed circuits and suction preferable
 - g. ENT equipment brought into final position when anaesthetist advises and all surgical suction connected
 - h. Laryngoscopy using CMAC and local anaesthetic slow application, mask/scope kept in kidney dish near head
 - i. Collection of nasal/oropharyngeal swab for COVID-19 test by surgical team
 - j. Consider topical application nasal oxymetazoline (syringe or pledget) to reduce secretions and improve air flow
 - k. Consider topical application povidone iodine to nasal (syringe or pledget) or oral cavity (Raytec)

6. **AEROSOL GENERATING PROCEDURE – minimise aerosolisation, open airway time and staff exposure**
 - a. Surgeons hands stay under the plastic drape, slower movements, minimise excessive drape elevation
 - b. Scout nurse to assist with image capture
 - c. If airway suctioning necessary, surgical assistant to occlude suction tubing until advised to release
 - d. Spontaneous ventilation technique using Parson's laryngoscope (+/- ventilating side port for insufflation)
 - i. Lowest gas flows to maintain oxygenation, stop flows each time instruments inserted/withdrawn
 - ii. Initial look with Hopkins rod (could have ETT loaded over it) or ventilating bronchoscope with bridge
 - iii. Advantages – familiar, efficient, unobstructed view, dynamic assessment, FB position stable
 - iv. Disadvantages – open airway, more aerosolisation
 - e. Alternative techniques with less aerosolisation:
 - i. Apnoeic technique – suitable for quick diagnostic look, positive pressure may move foreign body
 - ii. Flexible bronchoscopy via LMA or ETT (needs self-sealing suctioning adaptor, 1.9mm flexible forceps will fit down working channel of size 5.0 AMBU disposable bronchoscope) – partially obstructed ventilation, instruments too big for small child, less familiar technique, reduced clarity, may be difficult to withdraw foreign body into ETT and require piecemeal removal

7. **PROCEDURE COMPLETION**
 - a. Deep extubation spontaneously breathing, suction oropharynx, inline ETT suction if present, face mask ready
 - b. Supervised removal of plastic drape over patient face and box by rolling surface facing patient under and away
 - c. Slide Perspex box/Mayo stand away or detach operating table side arms if using, remove eye tapes slowly
 - d. Supervised slow removal of torso plastic drape by rolling inwards on itself and down toward the feet
 - e. ENT and scrub team to step to the back of the room with all equipment available in case of laryngospasm
 - f. Surgical mask on patient's face if will tolerate it, low flow oxygen via NP under the mask/Hudson mask on top
 - g. Recovery will occur in the operating room, notify recovery nurse if attending
 - h. Notify destination location, operating assistants, cleaning services when ready to leave theatre suite
 - i. Save images on computer and dedicated COVID USB, formally shut down tower computer before powering off

8. **SURGICAL AND ANAESTHETIC STAFF STAND DOWN**
 - a. Careful doffing of PPE/PAPR as per flowsheet, hand hygiene – DO NOT TOUCH your eyes, nose, mouth or face
 - b. Shower and immediate change of scrubs
 - c. If COVID positive patient consider staff application of 0.5% povidone iodine gargles +/- nasal spray
 - d. Return to clean area to complete operation/anaesthesia note, sign count sheet, handovers, sign out PAPR
 - e. Avoid re-entering the theatre for 30 minutes after patient departed to allow aerosols to settle prior to cleaning
 - f. Back up images from the USB after cleaning process finished
 - g. Team debrief - communicate summary/actions for follow up to checklist lead for process improvement

Fig. 4. (continued)

considered an option at our institution. Care should be taken in an open airway to avoid administration of large volumes of topical treatments that may trigger laryngospasm.

Talking through the process from start to finish can be helpful for the whole team to hear. In the rare event of an arrest situation, the anaesthetic team are expected to manage within the room without activation of the general emergency call button until other staff with appropriate PPE or PAPR arrive (concept of "Protected Code Blue" [11]). The post-operative strategy including reversal of anaesthesia to minimise coughing and aerosol generation, recovery location, recovery

staff involvement and transfer destination should also be communicated.

3.2.4. Confirm positioning

Prior to commencing the case, designating the orientation of the operating table, position of staff, equipment, cables, suction, sharps bins, and waste disposal units can be helpful to streamline the procedure, patient transfer in and out, lessen theatre door opening and time wastage. The anaesthetic team should allocate sites to place contaminated masks and laryngoscopes that may be required at later stages

to minimise contact exposure for both teams (e.g. disposable kidney dish on left side of patient near the head under plastic drape). Alternative warming technologies are employed rather than forced air warming blankets (such as 3M Bair Hugger™).

Further barrier precautions between the patient and team may be considered depending on the level of PPE available and type of procedure. This can include items such as a clear perspex box [28], operating table side arm used for suspension microlaryngoscopy, screening bar attachment, or even a Mayo instrument table with the solid tray removed, draped with a large clear plastic sheet to limit aerosolisation in the room but allow for unhampered hand movements during manipulation of the airway [22,29]. The clear plastic can be secured to the operating table with adhesive drape tape at the free edges to prevent air escape and slippage, only keeping access for instruments unrestricted. Ideally these measures should have been trialled in a simulation setting beforehand to identify any visual or ergonomic concerns and the choice made available in the room before the patient arrives.

Clear plastic drapes however, may encourage condensation and the formation of droplets, which can contaminate surfaces underneath it, especially the anaesthetists and surgeon's hands and forearms, the patient's face and surrounds. A suction device or smoke evacuator under the plastic drape may draw aerosols away from the operators and if used, should be secured as close to the source of aerosol emission as possible such that flow is directed caudally away from the team but not in a position to interfere with anaesthetic gas delivery. At our institution, a plastic backed absorbable underpad sheet (395 × 550 mm "blue sheet") is placed beneath the patient's head and a smaller clear plastic drape over the patient's exposed torso to allow visualisation of chest movements and to reduce surface contamination of the patient, adjacent operating table and linen [22]. A team member is designated to oversee careful drape removal at the end of the case to reduce the risk of contact spread and rapidly dispersing concentrated aerosols.

3.2.5. Confirm essential equipment required inside the operating theatre

The surgical and anaesthetic teams each have essential equipment and consumables required to be kept inside the operating theatre for AGP. Anaesthetic drugs should be drawn up and labelled in disposable trays to minimise the need to access the drug trolley. These requirements can be detailed beforehand on preference cards based on local practices and supplies available. However, it is advisable that the surgeon and anaesthetist in charge confirm what they anticipate will be required for that specific procedure and not just rely on a pre-prepared list, to limit having to search for things outside the room once the procedure has commenced and to reduce wastage of unused items that will be deemed contaminated. Detailing the need not only for surgical hardware but other specific items such as size and types of syringes (e.g. luer lock), sizes of flexible forceps, topical medications, microbiology swabs, sputum traps and specimen containers with patient labels available, can be helpful beforehand to streamline the execution of AGP and allow the focus to be maintained on minimising aerosolisation.

3.2.6. Confirm potential equipment required immediately outside the operating theatre

Keeping potential equipment, drugs and consumables close at hand but not in the theatre will reduce time taken for the nursing runners to travel to stock rooms and search for items. Sterile reusable instruments that have been opened during AGP may be subject to a lengthy turnaround time for sterilisation after the case. If there are limited supplies in the institution (e.g. bronchoscopy grasper forceps), it may be preferable to keep anticipated instruments clean just outside the room to be handed in as needed. Technology can sometimes fail at crucial moments and unexpected pathology may make it prudent to have spare telescopes of various sizes and angulation, cameras and light leads also in close proximity. Extra anti-fog and warmed water can assist in poor endoscopic visibility situations arising from the temperature differential between the operating theatre environment and the patient's

lower airway. A range of airway devices (e.g. different endotracheal tubes, disposable or non-disposable flexible bronchoscopes with associated adaptors/connectors, endoscopic baskets and balloon catheters) may need to be available if the initial plan is altered.

3.3. Equipment and staff preparation

Once the full team huddle has been completed, the anaesthetic and surgical teams should have their own individual team huddles to prepare themselves and equipment they will be using. A brief moment should be taken for staff welfare (nutrition/hydration, bathroom use) and to remove personal devices such as watches, jewellery, pens, pagers and mobile phones to reduce their contamination. Back-up arrangements are made to cover the surgical and anaesthetic teams who will not be able to be contacted during the procedure. Patient details can be entered onto an image capture system at this point if being used. If COVID-19 status is unknown and no testing has occurred prior, a request form for an intra-operative swab is prepared so a specimen can be collected under general anaesthesia. In our institution this does not change the management or approach but will be useful for contact tracing (including for all involved healthcare workers) if the result is positive.

Communication methods within the operating theatre, and between the operating room and the outside should be checked as it can be extremely challenging to relay equipment needs through the closed doors when wearing PPE. PAPR in particular, generates background noise for each individual and muffles voices such that deliberate effort is required to speak slowly, loudly and clearly. Closed loop communication is essential for the smooth progression of the case and patience is required for the repetition this entails. Bluetooth headsets worn under PAPR may be an option if they are able to be inclusive for enough critical staff and be cleaned appropriately. Theatre phones, intercoms and walkie talkie devices if being used should be checked to be functional beforehand. In our experience, having a specific hand gesture to flag attention between the inside team members is useful. Writing messages on a small portable whiteboard or even simply paper on a clipboard can facilitate being understood within the operating theatre or for the inside team to communicate with the outside clean runners through the viewing window.

Hand hygiene and donning of PPE or PAPR is performed in line with local institution infection control practice. This should be rehearsed prior, ideally on several occasions, so that it is familiar and comfortable. If departmental rather than individually allocated PAPR are being used, keeping a register of the device user will be important for contact tracing in the event of a healthcare worker becoming COVID-19 positive. Name or role tags on the front of balaclavas or head coverings can be helpful as the team is likely to vary due to rostering, staff may be difficult to differentiate when in identical full PPE, and addressing an individual by name tends to be more effective for gaining attention.

All surgical instruments are opened and checked in the operating theatre. Surgical staff should test that the telescopes, forceps and suction devices are the correct size and length to fit through closed circuit ports. As we have encountered, this step can be crucial in a small child where rigid instrumentation has limitations in terms of access, concurrent ventilation delivery and therapeutic retrieval resulting in a prolonged airway procedure even with experienced team members. Depending on the layout of the room, endoscopic equipment should be connected, white balance and focus adjustments pre-completed, and instrument trolleys positioned so as to not impede access of the patient and their bed into the room.

3.4. Patient retrieval and arrival

When all teams are in agreement, the patient location is notified to prepare the patient and they are retrieved by the designated members. The patient preferably wears a surgical mask for the transport though

this may be variably tolerated by a child. A phone call should be made to update the operating theatre when the patient is about to depart to confirm readiness for arrival and to minimise patient waiting time in an open environment. In our institution, a photocopy of the patient's identifying details, pre-operative checklist and consent form are the only paperwork to accompany them and are destroyed after the case to reduce staff contamination following the procedure. A surgical check-in is performed on arrival to the theatre complex and the patient is brought directly into the operating theatre for the team time out (WHO Surgical Safety Checklist) to be performed. The anaesthetic bay is bypassed to keep it a clean area for the anaesthetic runner. Once the patient has entered the room, the team within the operating theatre do not exit it until the completion of the case to minimise external contamination.

3.5. Procedure commencement

The anaesthetic team commence induction using their preferred technique and instrumentation with the surgical and scrub staff staying out of the room or distanced from the head of the patient, preferably more than 1.5 m away in a cranial direction, until required to approach. Intravenous access is established by the "clean" anaesthetist and laryngoscopy is performed by the "contaminated" anaesthetist. Use of a video-laryngoscope is recommended to improve visualisation, reduce the need for repeated airway instrumentation and distance the anaesthetist from the airway. The shared screen may also allow the surgeon to obtain enough of an overview of the supraglottis and larynx prior to airway securement to not require direct re-examination of an open airway in some circumstances. If using, local anaesthesia or other topical preparations are carefully applied at this point.

In our institution a nasopharyngeal/oropharyngeal swab is collected for COVID-19 once the child is sufficiently deep but prior to the application of povidone iodine to these sites (avoiding irrigation or spraying). A tracheal aspirate obtained via a sputum trap may have a higher sensitivity for polymerase chain reaction (PCR) testing though care should be taken to collect this via a closed system. The patient is positioned and draped in the agreed manner.

3.6. Aerosol generating procedure

The goals when undertaking AGP during the COVID-19 pandemic are to minimise aerosolisation, reduce open airway time and avoid staff exposure. This may require a higher awareness to slow down familiar movements and reflexive behaviours. If working under a clear plastic drape the primary operator and anaesthetist should try to keep their hands under it, minimise excessive or rapid drape elevation as instruments are passed in and avoid touching other surfaces or items unnecessarily. Having instruments under the transparent drape may be possible if it is large enough to extend to the adjacent instrument table.

If an open airway technique is preferred for laryngo-bronchoscopy, the lowest gas flows to maintain oxygenation are used. Consider methods such as using insufflating channels on the laryngoscope to distance the anaesthetist's hands from the airway. An initial diagnostic look for dynamic and anatomical assessment with a Hopkins rod can allow for further procedure planning. Depending on the circumstances and patient size, an appropriate endotracheal tube loaded over the Hopkins rod during this look can be left in situ once the telescope is withdrawn to buy some time with a safely secured airway whilst other instruments are prepared. A rigid ventilating bronchoscope can be used for the same purpose and allows maintenance of visualisation. Accessories such as the rubber telescope guide, bridge attachment, Storz FLUVOG adaptor and guide piece with rubber stopper for the working channel assist creating a greater seal.

In the example of paediatric foreign body retrieval, the spontaneous ventilation technique can be more familiar and efficient, allow an unobstructed view and the position of the foreign body may be more

stable. Inhalational anaesthetic induction may be delivered via a standard face mask followed by several options including oropharyngeal insufflation (less mucosal manipulation than nasopharyngeal route), temporary placement of a laryngeal mask airway (LMA) or endotracheal tube, or immediate handover to the surgical team to take over management with their instruments of choice. If a face mask is used, excessive positive pressure is avoided however gentle support may be required to avoid atelectasis and alveolar derecruitment. The best airway seal will be obtained by inflating the cuff of an endotracheal tube but this may not always be appropriate or available depending on the size of the child or the condition being treated (e.g. child with croup, subglottic stenosis or proximal airway foreign body).

Maintaining distance from the open end of airway devices is advised. To avoid close direct visualisation and suction through a rigid bronchoscope, the use of a glass window plug, flexible suction catheter and endoscopy forceps through the working channel can help if other endoscopic equipment is not available or suitable but may have its limitations. There will however, be circumstances where having an open airway is unavoidable such as retrieval of a laryngeal foreign body. Suction in this situation should be minimised as much as possible. With all airway manipulation, nursing staff and/or surgical assistants need to occlude suction tubing and only release it when signalled. Similarly, the anaesthetic team should communicate with each other to stop gas flows during periods when the rigid bronchoscope or other airway devices are being inserted or withdrawn.

Alternatively, flexible bronchoscopy can be employed via a LMA or endotracheal tube via self-sealing adaptors to reduce aerosol exposure for staff. The LMA does not provide a complete seal but may be a better alternative to an open airway in situations where avoiding intubation is preferable. Flexible bronchoscopy can be useful for a diagnostic assessment, however, it is generally a less familiar approach, ventilation can be obstructed by the presence of the scope in an endotracheal tube, the scope may be too big for a small child, the working channel is smaller and longer limiting therapeutic instrumentation available, it may be harder to manipulate and maintain coverage under plastic drapes and the image quality may be inferior to the rigid telescope. Final smooth withdrawal of an airway foreign body using flexible forceps may be hampered by the size of the material and the holding strength of the forceps. Flexible endoscopy forceps that are small enough to fit through working channels are usually designed for taking biopsies and may break an organic foreign body into smaller pieces necessitating multiple passes for complete retrieval.

The use of an apnoeic ventilation technique via rapid sequence induction or at later stages of the procedure can be considered to reduce aerosol generation but should only be undertaken if both the anaesthetist and surgeon are comfortable with the method and feel that it is suitable for the patient and the condition being managed. The time available for airway assessment and instrumentation by the surgeon is reduced, single lung ventilation may be more challenging in the situation of an occluding foreign body in a main bronchus, and if positive pressure is required, the position of an unstable foreign body may alter.

3.7. Procedure completion

The completion of AGP will bring relief to all involved especially after the lengthy preparation and vigilance required, however elevated attention to aerosol exposure needs to be maintained by the whole team during anaesthesia reversal, whether it occurs with or without extubation. The anaesthetic team may prefer to keep plastic draping or screening attachments in situ to distance themselves from a coughing, gagging or crying child, and remove it after the patient is in a more settled state. A designated team member (e.g. anaesthetic nurse) is delegated to supervise plastic drape removal by several staff members together, to ensure the contaminated surface is rolled slowly onto itself and away from staff in a caudal direction before discarding. Accessories under plastic drapes such as the perspex box or side arm must be

carefully detached, as they will potentially have contaminated surfaces. Patient eye tapes need to be removed slowly. Depending on the procedure, the surgical team should distance themselves from the patient but may need to stay in the operating room with all equipment still connected to assist in the event of laryngospasm or unexpected deterioration.

Once stabilised, a surgical mask is placed on the patient's face if tolerated. Supplemental low-flow oxygen can be delivered either via nasal prongs under the surgical mask or a Hudson mask on top of the surgical mask. Local preference will dictate whether the patient stays in the operating room for their recovery or is transferred to another location. In our institution the patient is recovered in the operating theatre with the anaesthetic team and a recovery nurse who will also escort them out. Transport to the final destination should involve a notification to the receiving area, operating assistants and cleaning services, to minimise delays and allow preparation for arrival. Images and videos from the image capture device can be saved and backed up at this point prior to powering down in preparation for terminal cleaning.

3.8. Surgical and anaesthetic staff stand down

When the anaesthesia team are satisfied with the patient's progress, the surgical staff may stand down. Careful and deliberate doffing of PPE or PAPR is essential to avoid self-contamination of healthcare workers. An experienced spotter is invaluable to assist the process otherwise prior training and regular practice is highly recommended to allow the team to help each other in the correct sequence and technique. Hand hygiene and avoiding touching their own faces, conjunctivae and mucous membranes is essential. Staff should immediately shower and change scrubs especially if the PPE or PAPR available does not provide complete front and back skin coverage. If the patient is known to be COVID-19 positive, self-administration of 0.5% povidone iodine gargle for 30 s and/or topical nasal application may be considered by those closely involved with the procedure [27].

The surgical team can then return to designated clean areas to complete the operation note, sign the surgical count sheet and provide handovers. The operating theatre is not re-entered once the patient has departed for 30 min to allow aerosols to settle and ventilation exchange prior to cleaning. This period of time can be variable between institutions depending on the number of air changes per hour in the operating theatre. Once the anaesthesia team have completed their care of the patient they may need to return to the operating theatre complex for their own doffing if that is the safest place for it to be performed under supervision and for access to showers prior to completing their own paperwork.

The time taken from the commencement of the full team huddle to when all involved have stood down after the completion of the procedure has been considerably lengthy in our experience. All team members may be exhausted however a team debrief to communicate feedback is essential to improve the process for forthcoming procedures as subsequent high-risk AGP are unlikely to be performed by exactly the same participants. It may be helpful to assign a clinical lead from the Otolaryngology department or several leads for subspecialty interest groups (e.g. paediatric airway, rhinology, otology, head and neck) to provide oversight for each AGP checklist used at the institution and to be the person to incorporate and distribute recommendations after each case to enhance it.

4. Discussion

Teamwork, collaboration and communication are essential in usual surgical practice but even more so at present. A unified team approach can provide reassurance in a time of overwhelming change, resource rationing, anxiety about risk, and confusion about which hospital department flowsheet to follow. Surgical, anaesthesia, nursing and

operation assisting staff should be encouraged to contribute even seemingly minor details to help improve the process of performing AGP efficiently and minimising their exposure to SARS-CoV-2 in the context of their own facilities and resources.

It can be helpful to print an operative team checklist in a concise format to keep it less intimidating. The overall template can be maintained for different AGP with substitution of relevant anaesthesia and surgical requirements. The intention is not to be prescriptive but to raise awareness of techniques to modify practice. Even if experienced with undertaking AGP in normal situations, a checklist of alternative approaches can be a reminder that things need to be done differently to reduce droplet, contact and potential airborne transmission, and highlights other risk management steps of the patient journey that the team are not usually collectively involved with.

Treating all high-risk AGP as potentially COVID-19 positive at present, has been time and resource intensive but invaluable in terms of real life simulation and team training. This may not be sustainable as disease prevalence fluctuates and the criteria of what constitutes a high-risk procedure or high-risk patient changes, however it has allowed for preparation and system planning. Like all new approaches there is a learning curve before attaining proficiency and mannequin simulation can be substituted to provide ongoing skill maintenance. Developing and improving the checklist involved stepping back to take an outsider's view (not unlike that of the PPE spotter) with the general principles of approach in mind (Fig. 3), to raise awareness, alter behaviour and potentially reduce transmission. To date, every AGP undertaken at our institution using this process has resulted in a refinement of our practices and will continue to do so in the future.

Recommendations for risk reduction for healthcare workers during the COVID-19 crisis will undoubtedly evolve as the pandemic unfolds and more is understood about the virus itself. An operative team checklist and its execution however, are no substitute for meticulous hand hygiene, respiratory etiquette, environmental cleaning and disinfection, and physical distancing as recommended by the WHO, for healthcare workers both within the healthcare environment and when in the general community.

5. Conclusion

An operative team checklist detailing the immediate pre-operative, intra-operative and post-operative handling of patients who are COVID-19 positive or whose status is unknown is suggested to prompt healthcare workers to modify usual practices to reduce their exposure to SARS-CoV-2 during AGP. In a time of rapidly growing information and changing recommendations, a concise checklist customised for local needs may alert frontline staff of subtle techniques to reduce droplet, contact and airborne transmission, and help provide focus during these situations of close infectious contact.

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Declaration of competing interest

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