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Title: Bronchoscopy safety precautions for diagnosing COVID-19 associated pulmonary aspergillosis - a simulation study

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Ethical approval

The authors confirm that the ethical policies of the journal, as noted in the author's guideline page, have been adhered to.

Author contributions:

P.K., O.A.C. and M.K. conceived the study, developed the model, performed analyses, discussed the results and their implications, and wrote the manuscript. All authors had full access to all data in the study and take responsibility for the integrity of the analysis.

Conflict of Interest

PK has received non-financial scientific grants from Miltenyi Biotec GmbH, Bergisch Gladbach, Germany, and the Cologne Excellence Cluster on Cellular Stress Responses in Aging-Associated Diseases, University of Cologne, Cologne, Germany, and received lecture honoraria from or is advisor to Akademie für Infektionsmedizin e.V., Astellas Pharma, Gilead Sciences, GPR Academy Ruesselsheim, MSD Sharp & Dohme GmbH, Noxxon N.V., and University Hospital, LMU Munich outside the submitted work.

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Summary

Objectives: With the outbreak of coronavirus disease 2019 (COVID-19), clinicians have used personal protective equipment to avoid transmission of severe acute respiratory syndrome coronavirus 2. However they still face occupational risk of infection, when treating COVID-19 patients. This may be highest during invasive diagnostic procedures releasing aerosols and droplets. Thereby the use of diagnostic procedures for Covid-19 associated aspergillosis may be delayed or impeded, as use of bronchoscopy has been discouraged. This leads to avoidance of a crucial procedure for diagnosing invasive aspergillosis. We intent to visualize aerosol and droplet spread and surface contamination during bronchoscopy and address which measures can avoid exposure of health care workers.

Methods: We created a simulation model to visualize aerosol and droplet generation as well as surface contamination by nebulizing fluorescent solution detected by using ultraviolet light and slow motion capture. We repurposed covers for ultrasound transducers or endoscopic cameras to prevent surface and ambient air contamination.

Results: In our bronchoscopy simulation model, we noticed extensive aerosol generation, droplet spread and surface contamination. Exposure of health-care workers and contamination of surfaces can be efficiently reduced by repurposing covers for ultrasound transducers or endoscopic cameras to seal the tube opening during bronchoscopy in mechanically ventilated patients.

Conclusion: Adequate personal protective equipment and safety strategies allow to minimize contamination during bronchoscopy in mechanically ventilated COVID-19 patients.

Introduction

Health-care workers (HCWs) are at increased occupational risk of infection, when managing coronavirus disease 2019 (COVID-19) patients.[1] Such risk may be highest during invasive diagnostic procedures releasing aerosols and droplets.[2] Use of bronchoscopy and bronchoalveolar lavage (BAL) has thus been discouraged in patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. In intubated patients, tracheal aspirates and other respiratory specimens should be considered instead. Many mechanically ventilated COVID-19 patients suffer from acute respiratory distress syndrome (ARDS), and standard treatment comprises positive pressure-controlled ventilation with application of positive end-expiratory pressure (PEEP), respiratory gas humidification and temperature control. During intensive care for COVID-19 patients, however emergency bronchoscopy may be required. Massive hemoptysis (>200ml/24h), foreign body removal, airway obstruction or atelectasis due to mucus plug are immediate threats to patient life. Any of these emergencies can force physicians into greater risk of exposure to SARS-CoV-2,[3] and to open the closed respiratory circuit. Aerosol and droplets from tubes and mounts may harbor SARS-CoV-2 which will then be released into ambient air. To diagnose secondary infection, and especially COVID-19 associated pulmonary aspergillosis (CAPA) lower respiratory samples obtained by BAL are the samples of choice.[4,5] However due to its restricted use, non-validated tests have been used from upper respiratory tract specimen.[6] By avoiding the standard diagnostics, secondary infections could be missed or diagnosed with delay. Furthermore, localized infections such as tracheobronchitis cannot be visualized and the possibility of obtaining biopsies or direct samples are missed.[7] To endeavor this we simulated bronchoscopy in an intubated patient and visualized aerosol and droplet release. We discuss measures to avoid exposure of health care workers.

Material & Methods

Bronchoscopy simulation model:

We created a simulation model using a modified resuscitation simulator (Laerdal Resusci Anne simulator, Puchheim, Germany). The simulator was intubated (cuffed endobronchial tube, size 7.5, RÜSCH™, Teleflex Medical GmbH, Fellbach, Germany) and a smoothbore catheter mount 180mm (INTERSURGICAL, Wokingham, United Kingdom) was attached. We connected an artificial lung (Dräger SelfTestLung™, latex, 1.5L, Drägerwerk AG & Co. KGaA, Lübeck, Germany) and connected a nebulizer (Aerogen® Pro X controller and Aerogen® Solo nebulizer, both Ratingen, Germany) to generate aerosol. Aerosol and droplet spread was visualized by nebulizing 2mL of fluorescent solution for verification of hand disinfection procedures (Schülke optics training disinfectant, Schülke & Mayr GmbH, Norderstedt, Germany) and detected by using ultraviolet light flashlights (395nm, YOUTHINK, Zagreb, Croatia) as described previously.[8] UV-protection glasses were used. Positive pressure ventilation was simulated by using an Ambu® SPUR® II single patient use self-inflating bag (Bad Nauheim, Germany). Condensed water in the closed circuit was simulated by applying 1mL fluorescent solution for verification of hand disinfection procedures (Schülke optics, Schülke & Mayr GmbH, Norderstedt, Germany) into the smoothbore catheter mount. All simulations were performed at room temperature. We used an endoscopy telescopic drape (SteriVision™ Plus Telescopic drape, merosystems™, Berlin, Germany) and cut a small hole into the distal end (1x1cm, fitting to the tube mount). We sealed the proximal end of the cover with a tie-wrap close to the bronchoscope handle. An Ambu® aScope™ 4 Broncho Large (5.8/2.8) single use bronchoscope (Bad Nauheim, Germany) was used. Video recording from different angles was done with two Apple™ iPhone 11 Pro in parallel (Cupertino, CA, USA). For every video take the dressing at the model's chest and gloves were changed to avoid contamination and fluorescent training solution was re-applied within the nebulizer and smoothbore catheter mount. We used the preinstalled slow-motion camera mode with 240fps. Video editing (cutting only, adding fade-in and outs and arrows; no postproduction increase of colors or contrast) was done with Wondershare Filmora 9 (Wondershare Software Co., Ltd. Shenzhen, Guangdong province, People's Republic of China). No IRB approval was needed for this educational study.

Preparation and Equipment

Apply single use bronchoscopes to eliminate requirement to clean scopes and risk of cross contamination, and to increase portability and out-of-hours availability. Prepare sample tubes including adequate labelling and fill in laboratory and transport forms and saline in syringes for lavage. Start preoxygenation. Follow pertinent respiratory and contact precautions specified by the Center for Disease Control and Prevention (CDC) [9], Infectious Diseases Society of America (IDSA) and the guidelines of your country, region, and own institution.[10] Follow all guideline updates as current recommendations may be revised in future. Have a colleague present to ensure correct donning and doffing of personal protective equipment (PPE) with the use of a checklist double checking appropriate disinfection steps, sealing, and identifying any equipment breaks.[11] Wash your hands with soap and water or use an alcohol-based hand sanitizer or hand rub. Dress yourself in the protective gown. Put on a pair of non-sterile gloves. Put on a protective N95 or FFP3 mask, and a face shield. Put on a pair of sterile gloves (Figure S1). From here all procedures should be performed using sterile material (covers, scissors, and gloves). Insert the bronchoscope into the sterile cover and seal the cover with a tie-wrap close to its handle at the proximal end. Cut a hole – corresponding to the diameter of the endotracheal tube mount – into the tip of a sterile cover used for ultrasound transducers or endoscopic cameras. Insert the endotracheal tube mount into the sterile cover and fix it with adhesive tape, while the bronchoscope rests in the sterile cover (Figure 4A). Apply suction to the bronchoscope.

Results – Simulation model

Upon opening the closed respiratory circuit, the following critical situations appear: Opening the tube mount releases a spray of droplets to the patient chest and abdomen as well as an aerosol (Figures 1A, 1B). The direction of the flip top cap being opened, and the fingers of the examiner determine the direction of the aerosol (Video 1, Video S1) **(Critical phase 1)**. The sudden release of pressure by opening the closed respiratory system and the continued operation of the ventilator lead to distribution of aerosol and droplets within the room. Inserting the bronchoscope causes turbulence and deflects droplets into multiple directions (Video 2, Figures 1C, 1D, Figure S2) **(Critical phase 2)**. Removal of the bronchoscope and closure of the flip top cap causes deflection of droplets (Video 3, Video S2, Figure 2A) **(Critical phase 3)**. Depending on the trajectory of the aerosol and droplets profound surface contamination can be detected at the patient's chest as well as on the examiner's fingers (Figure 3). Installation of a simple cover fixed with adhesive tape to the tube mount and rear end of the bronchoscope leads to a significant reduction of aerosol and droplets being distributed within the room (Video 4, Figure 2B, Figure 4). See further material in the online-supplement.

Discussion and conclusion

Throughout the course of the COVID-19 pandemic, much remains unknown about the risk of transmission between patients and caregivers.[1] Our study investigates protection and safety precautions during simulated bronchoscopy in intubated patients to reduce a potential transmission between the patient and health-care workers. There are several limitations to our model. Lung resistance and compliance differ from human anatomy and physiology of the respiratory tract. The use of a self-inflating bag and simulating ventilation by hand may have under- or overrated the actual aerosol or droplet generation in comparison to controlled mechanical ventilation. UV torches emit a cone-shaped illumination, so that we might have missed aerosol and droplets outside the cones. We simulated condensed water resulting from respiratory gas humidification and temperature control by fluorescent training solution applied into the tube and smoothbore mount. This may have influenced droplet formation. However, our model suggests that a simple cover results in a significant reduction of air and surface contamination. Besides adequate PPE the implementation of a WHO style checklist[12] and team timeout lead to standardized procedures potentially reducing the occurrence of hazardous errors. The longer the ventilator circuit remains opened, the higher the contamination. Therefore, caregivers need to work quickly and focused. The following simple steps can reduce contamination. If a closed suction is mounted, remove as much water condensed in the tubing as possible. Place an absorbent sheet on the chest of the patient, at the area of expected maximum contamination. Place a blunt clamp at the tube, then quickly remove the closed suction. Ask a colleague to perform an inspiratory hold on the respirator when opening and when closing the flip top cap or opening the closed ventilation system. Reduce number of health care workers involved to a minimum. Hospital-wide SARS-CoV-2 screening is needed to identify asymptomatic and presymptomatic health-care workers that perform high risk procedures and thereby prevent in-hospital transmission.[13] Use single use bronchoscopes if possible, to reduce the material needed in the room and to exclude cross-contamination by discarding the bronchoscope after the procedure. Use closed-loop sampling systems. If available, use a repurposed cover as described to decrease the risk of airborne droplets, aerosols, and contaminated surfaces (including the hands of the examiner (Figure 4B). Ultrasound transducer covers or covers for endoscopic cameras are widely available and easy to repurpose. If possible, train handling of the procedure with a model. Plastic vials containing the material sampled must have their external surfaces disinfected before sent for analysis. A thorough disinfection of all surrounding devices is mandatory after the procedure (tables, devices, floors etc.).[14,15] Therefore a potential benefit arises with the reduced risk of patient-derived *A. fumigatus* contamination in the intensive care unit rooms and potentially preventing patient-to-patient transmission from colonized or infected patients during bronchoscopy.[16-18] Our strategy can easily be transferred to management of other infections, for example tuberculosis, influenza, or Middle East Respiratory Syndrome (MERS)-CoV, when aerosol-generating procedures put caregivers at risk of infection. This could possibly have serious implications in avoiding nosocomial transmissions between patients and caregivers.

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Figures

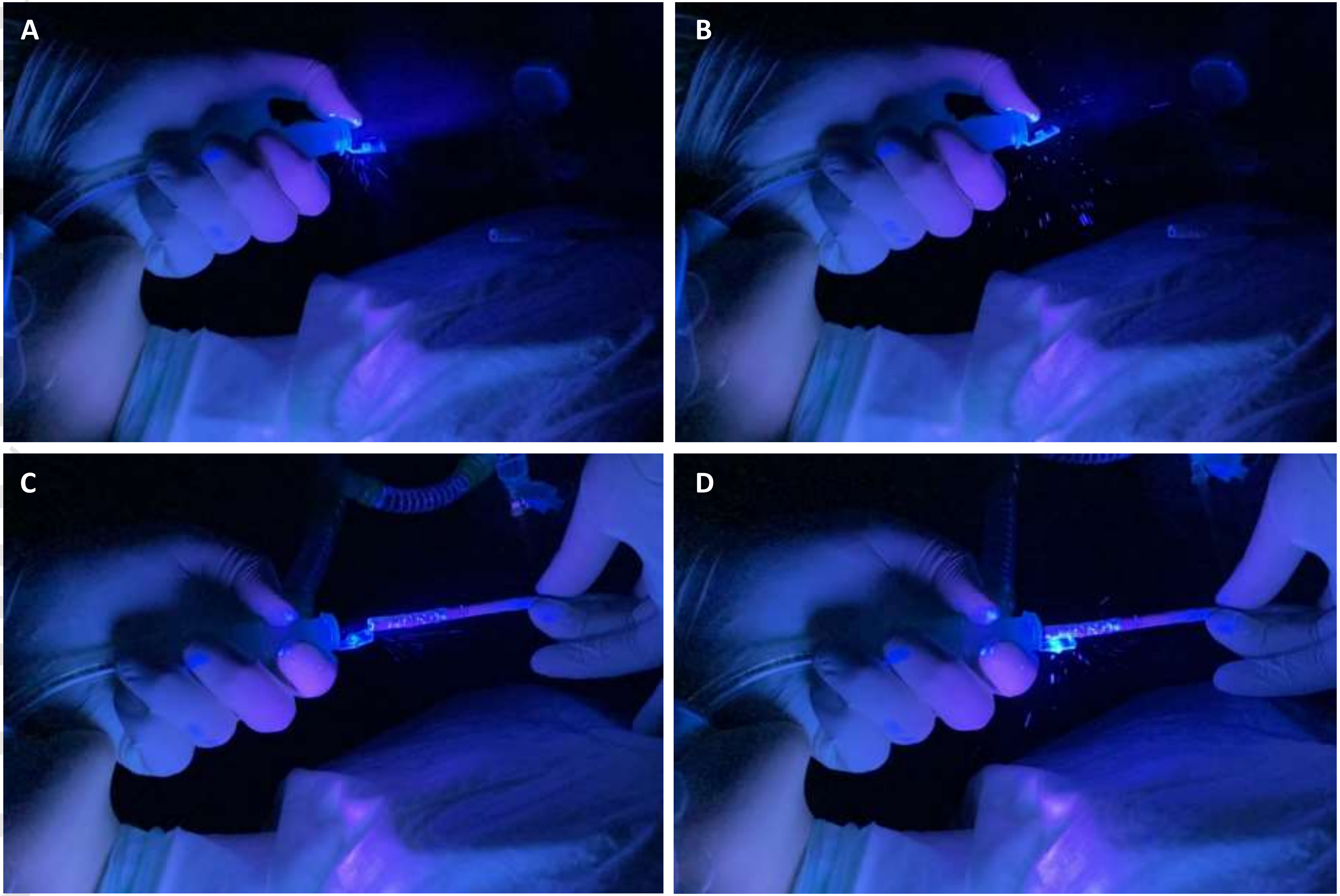

Figure 1A and B. Opening of the flip top cap at the tubing's smoothbore mount. Note aerosol and droplets at the end of the insertion site of the tube being sprayed. **C and D** Bronchoscope insertion without cover leading to surface and air contamination.

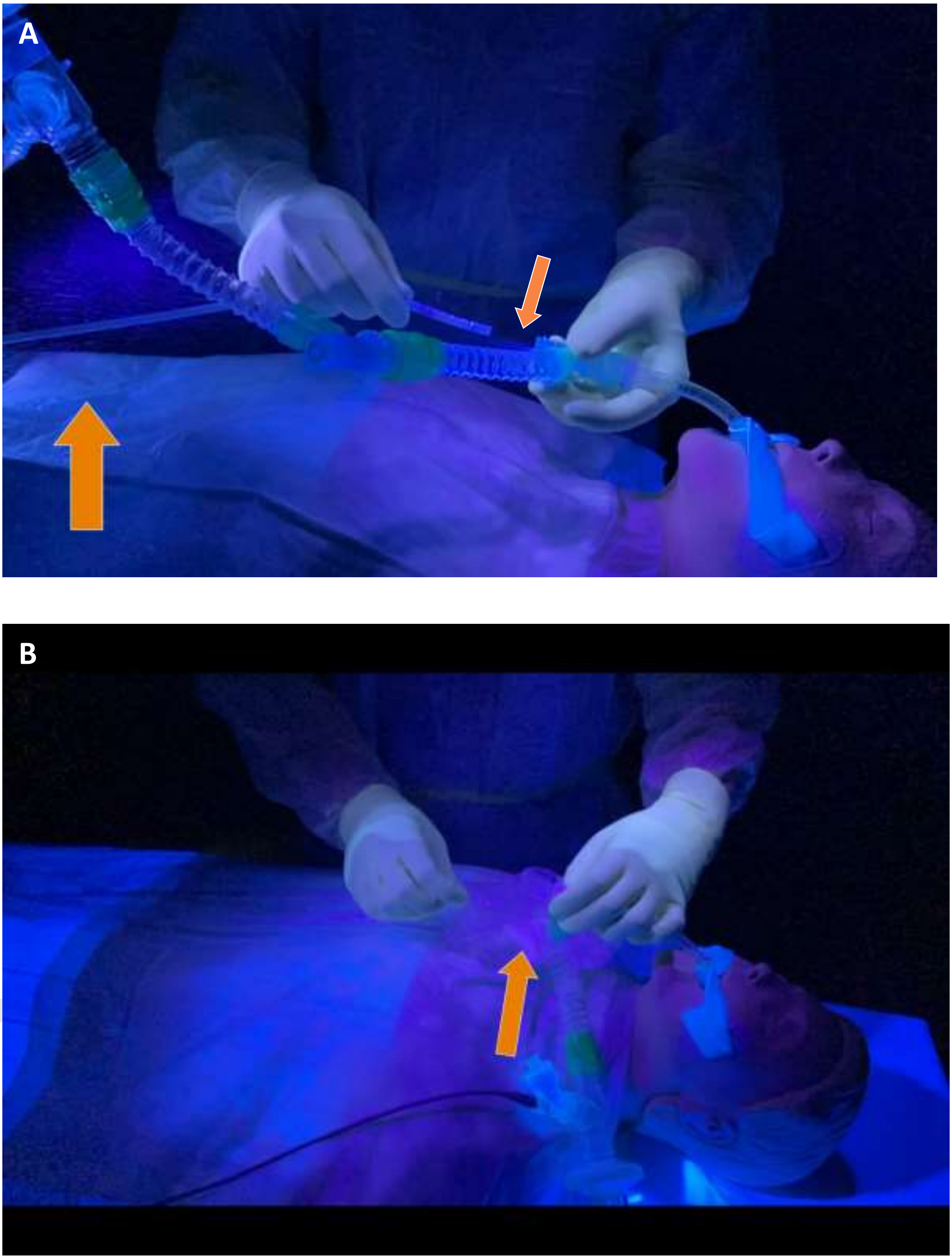

Figure 2 A Bronchoscope removal without cover. Aerosol and droplets at the end of the insertion site of the tube (small arrow) being tossed across the patient chest and abdomen

into the room (large arrow).**B** Bronchoscope insertion with cover (arrow) at opening the insertion site.

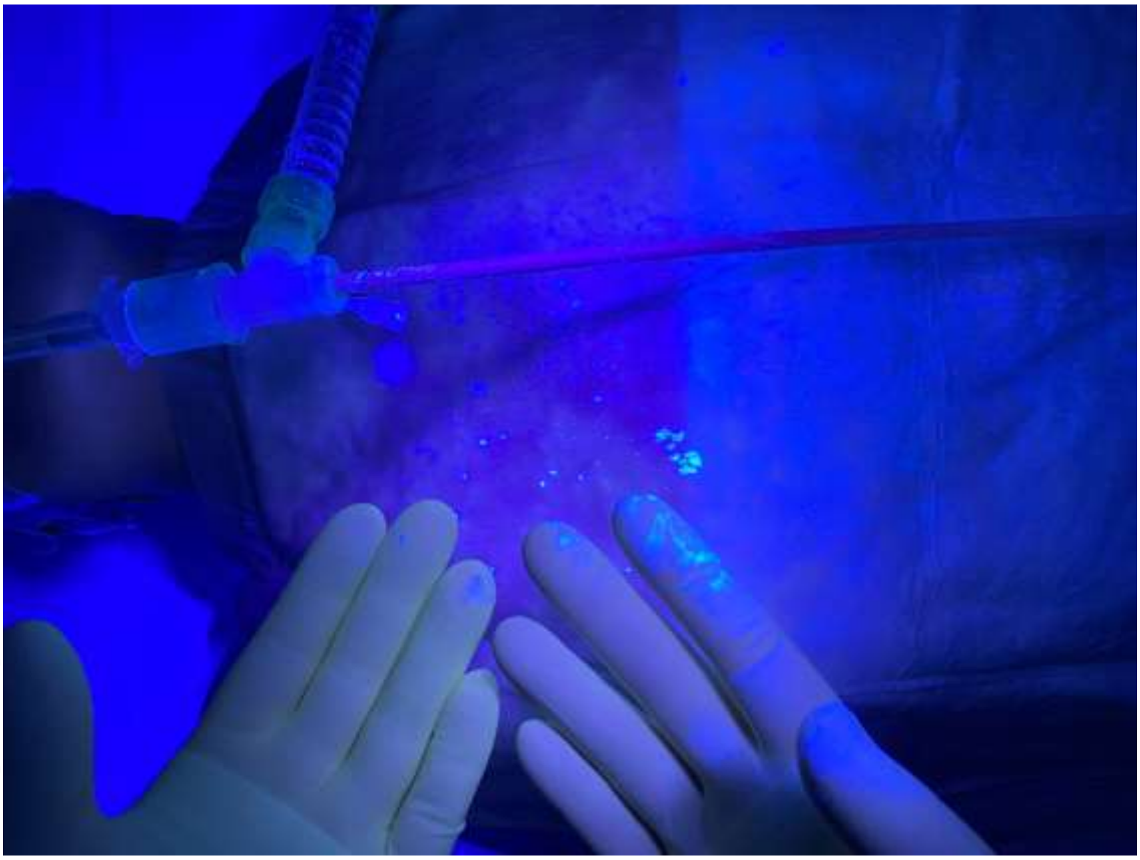

Figure 3.

Bronchoscopy without cover. Note the contamination on the surfaces on patient chest and examiner fingers.

Figure 4.

Bronchoscopy with repurposed cover. **A** Set-up for bronchoscopy with repurposed cover. **B** After simulated bronchoscopy. Note the missing contamination on the surfaces on patient chest and examiners fingers but small fluorescent droplets within the tube and cover / adhering to the bronchoscope.

Videos

Video 1. Opening of the flip top cap at the tubing's smoothbore mount. The opening angle and the fingers of the examiner determine the trajectory of the aerosol and droplets downwards to the patient chest (arrow).

Video 2. Bronchoscope insertion without cover. Aerosol and droplets at the end of the insertion site of the tube spraying across. Inserting the bronchoscope causes turbulence and deflects droplets into multiple directions. Note the fluorescent dye at the fingers of the examiner.

Video 3. Bronchoscope removal without cover. Note aerosol and droplets at the end of removal spray at least 21 inches (55 cm). Single droplets are expelled due to the corrugated distal end of the bronchoscope.

Video 4. Opening of the flip top cap at the tubing's smoothbore mount and insertion of the bronchoscope in a repurposed cover. Moment of flip top cap opening is indicated by appearing arrow.