Original Article

# Simulation with a colour indicator to help reduce contamination during airway management in COVID-19 times: An experience from a tertiary centre in India

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## ABSTRACT

**Background and Aims:** The coronavirus disease 2019 (COVID-19) pandemic has initiated modified protocols for aerosol-generating procedures. A simulation study using dye was conducted to highlight contamination at intubation and extubation and to encourage adherence to the new COVID-19 protocol among anaesthesia personnel in our institution. **Methods:** A video demonstrating the new COVID-19 protocols was circulated in the Department of Anaesthesiology a week prior to the study. Thirty teams, each comprising an anaesthesia resident and a staff technician, were enroled. Each team was asked to demonstrate the steps of preparation, intubation and extubation on a mannequin in a COVID-19 scenario. Checklists were used to assess points of contamination and adherence to the protocols. Following debriefing, a repeat simulation was conducted. The use of a dye highlighted the points of contamination. The study subjects provided feedback on the usefulness of the session and practical difficulties encountered in adapting to the new protocols. **Results:** The average contamination scores decreased by 3.4 (95% confidence interval (CI): 2.4–4.4, $P < 0.001$) in the post-debrief session. Adherence to the steps of the modified protocol improved by a score of 2.7 (CI: 3.6–1.83) among anaesthesiologists and by 4.3 (CI: 5.3–3.3) among technicians. Further, 93% felt that the use of the colour indicator reinforced awareness of the possible points of contamination. **Conclusion:** Simulation with a low-fidelity mannequin by using colour indicator for secretions is an effective teaching tool to reduce health hazards during airway management in COVID-19 times.

**Key words:** Anaesthesia, COVID-19, equipment contamination, simulation training

## INTRODUCTION

All across the world, more than 1,15,000 healthcare workers have died due to coronavirus disease 2019 (COVID-19) according to the World Health Organization.[1] Anaesthesiologists are particularly vulnerable to infection risks, given that airway management is a part of their daily practice. Contamination of the operating room (OR) work environment with airway secretions, which have a high viral load of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), have the potential to affect both patients and anaesthesia personnel.[2] The COVID-19 pandemic has been a catalyst in the development of innovative methods to deal with this grave challenge. Guidelines have been formulated with various barrier methods during airway management to reduce contamination and protect the anaesthesia personnel.[3-5]

Adopting the new recommendations can be challenging. Practice-based learning by using



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simulation techniques can facilitate familiarity and identify practical problems of implementation.[6] This study devised for anaesthesia personnel used a dye to highlight secretions. As airway secretions and aerosols are colourless, anaesthesia personnel can easily be caught off guard during airway management. The aim of the study was to impress upon the study participants the potential points of contamination and the need to follow the new protocols that focus on decreasing contamination and aerosolisation to create a safer work environment. The primary objective was to assess the points of contamination and adherence rate among study participants to the newly formulated department protocol in the baseline (pre debrief) and post debrief session by using a colour indicator as a teaching tool. A secondary objective was to assess the practical difficulties faced by the anaesthesia residents and staff anaesthesia technicians in following these revised protocols.

## METHODS

A quasi-experimental study was conducted in the Department of Anaesthesiology in a tertiary care, teaching hospital in India. Approval was obtained from the institute's review board and ethics committee. Written consent was obtained from all the participants to publish the data obtained. This manuscript follows STROBE guidelines.

Our department conducts approximately 48,000 anaesthetics annually, and we have a workforce of more than 160 anaesthesia personnel. This simulation study was conducted over 4 days in the operation theatre. The inclusion criteria were current second and third-year anaesthesia residents and staff anaesthesia technicians with at least 1 year of work experience.

At the outset of the COVID-19 pandemic, a department protocol was developed for airway management according to the available evidence.[3,7,8] The staff and students were familiarised with these new concepts through group discussions on Microsoft teams. Based on this protocol, a video was made demonstrating the correct sequences and steps at intubation and extubation. This video was circulated to all members of the anaesthesia department a week prior to the study and was part of routine dissemination of COVID-19 information. The participants were unaware that a study would be conducted.

On the day of the simulation, all anaesthetic drugs and equipment, including the newer equipment designed specifically for use in the COVID-19 scenario, were kept available in the OR. A low-fidelity mannequin (Laerdal airway management trainer) was used. To simulate secretions, a mannequin compatible dye (Laerdal polyethylene glycol) [Figure 1a] was used to stain the oral cavity and was sprayed to simulate coughing during extubation. An ampoule with the dye was placed in the oral cavity of the mannequin to simulate secretions for suctioning. Personal protective equipment (PPE), specifically N95 masks, gloves, gowns, head hoods, visors and goggles, were placed at the site of simulation. All equipment and reusable PPE were thoroughly cleaned between each simulation run. Strict COVID-19 protocols such as physical distancing, mandatory use of N 95 masks and use of hand hygiene by both participants and assessors were followed.[9]

Each team comprised an anaesthesia resident and a staff anaesthesia technician. The team was given a scenario of an elective surgery where the patient had to be given general anaesthesia. They were asked to

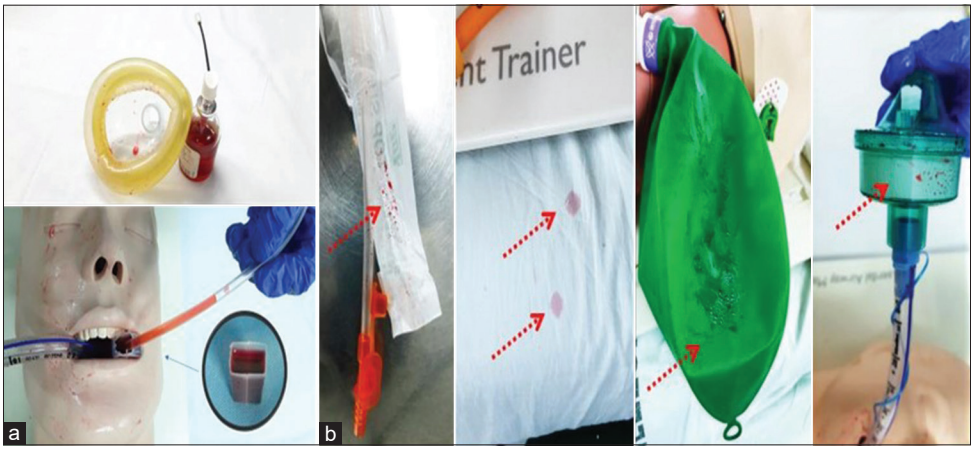


**Figure 1:** (a) Colour indicator used to stain the oral cavity; (b) Areas of contamination indicated by red arrows

demonstrate preparation for the case, steps of intubation and extubation in the context of the current COVID-19 scenario. One of the investigators played the role of a first-year resident who would do as instructed by the team (example: drug administration). The domains assessed were points of contamination (POCs) and steps of protocol (SOPs) for the anaesthesiologists and for technicians, respectively. Assessment was done by three independent observers by using checklists. The participants were unaware of what was being observed and assessed.

Once the baseline simulation run was over, the subjects were shown the areas of staining by the dye [Figure 1b], which reflected the points of contamination. A verbal debrief on their performance was done and they were asked to review the department protocol video on their mobile phones. Following this, a post-debrief simulation and assessment were repeated. Participants were asked to maintain the confidentiality of the study.

There were 20 potential POCs, each given a score of 1. There were 20 SOPs for the residents and the technicians, respectively, with a maximum score of 20 each. For residents, this score comprised 2 points for preparation, 10 points for intubation and 8 points for extubation [Annexure 1]. For technicians, it was 4 points for preparation, 10 for intubation and 6 for extubation [Annexure 2]. Data were noted in the data collection forms and collated in Microsoft Excel.

The primary outcomes assessed were the average contamination rate of the anaesthesia working space in the operating room (OR) and adherence rate to SOP during intubation and extubation of the mannequin at the baseline simulation and at the post-debrief simulation. At the end of the latter, feedback regarding the session and practical difficulties encountered in the OR was obtained from the participants. This feedback, in the form of 11 questions, was answered in the Likert scale format.

The two domains that were statistically analysed were the POCs and SOPs, with scores ranging from 0 to 20 each. Descriptive measures such as mean with standard deviation and/or median with interquartile range were measured for all continuous baseline variables, whereas frequencies and percentages were presented for all baseline categorical variables. Summative score for each domain was calculated. Paired t test was used to find the changes in scores of both domains before and after the intervention if data followed normal distribution. If data were not normally distributed, the corresponding non-parametric method, that is, Wilcoxon signed-rank test was used. The mean change, with bootstrapped 95% confidence interval (CI) was presented, if normal. Correlation analysis was also done to find the relationship between SOP and POC scores before and after intervention. Stratum-specific analysis was also presented. Unadjusted and adjusted analyses were carried out. Data were analysed using Statistical Package for Social Sciences for Windows (SPSS Inc. Released 2007, version 23.0. Armonk, New York, USA).

The average contamination rate of the anaesthesia workspace in a simulation study by Birnbach *et al*.[10] was reported as 20.3 (SD ± 9) out of the 40 possible contamination sites. To aim for a 50% reduction with alpha error at 1% and beta error at 10%, we needed to study 25 subjects. Considering a potential dropout rate of 10%, we studied 30 teams.

## RESULTS

The total number of teams were 30, with a resident and a technician in each team [Figure 2].

We found an average contamination rate of 7.03 out of 20 in the baseline simulation that decreased to 3.6 in the post-debrief simulation. The scores for steps of protocol improved from the baseline by 2.7 in anaesthesia residents and by 4.3 in technicians [Table 1].

The most common SOP not adhered to among anaesthesiologists was switching off the oxygen flows during airway management [Figure 3]. During intubation and extubation, 63.3% of residents (19 out of 30) failed to switch off oxygen, which decreased to 23.3% (7 out of 30) during the post-debrief session.

The most common SOP not adhered to by anaesthesia technicians was connecting the suction catheter. We found that only 40% of technicians connected suction catheter pre-debrief which improved significantly to 73.3% in the post-debrief session.

The points with the highest contamination rates were the laryngoscope handle, facemask, bed linen, heat and moisture exchanger (HME) filter and endotracheal tube [Figure 4].

We analysed the correlation between adherence to SOP and reduction in POC score. Significant

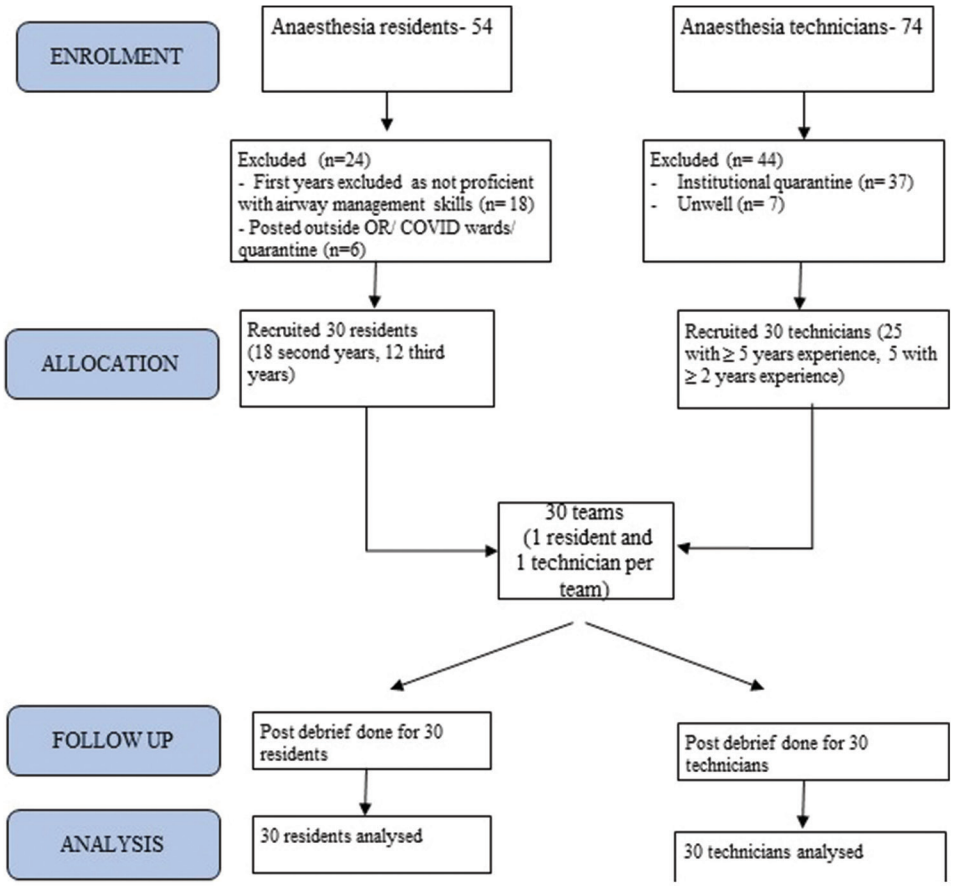


**Figure 2:** CONSORT diagram showing enrolment of study participants

**Table 1: Baseline and post-debrief scores of points of contamination and steps of the protocol for residents and technicians**

| Variables | Maximum score | Mean (SD) | | Difference in Scores (Baseline-Post debrief) | *P** |
|---|---|---|---|---|---|
| | | Baseline | Post debrief | Mean difference (Bootstrap 95% CI) | |
| Points of Contamination | | | | | |
| Points of contamination score | 20 | 7.03 (2.55) | 3.63 (1.35) | −3.4 (−2.4, −4.4) | <0.001 (0.00001) |
| Residents | | | | | |
| Preparation Score | 2 | 1.70 (0.54) | 1.87 (0.35) | | |
| Intubation Score | 10 | 7.57 (1.50) | 9.03 (0.85) | | |
| Extubation Score | 8 | 6.63 (1.45) | 7.73 (0.64) | | |
| Total Scores | 20 | 15.93 (2.41) | 18.60 (0.97) | 2.7 (3.6, 1.83) | <0.001 (0.000021) |
| Technicians | | | | | |
| Preparation Score | 4 | 2.90 (1.06) | 3.80 (0.55) | | |
| Intubation Score | 10 | 7.03 (1.87) | 9.07 (0.79) | | |
| Extubation Score | 6 | 3.97 (1.45) | 5.30 (0.70) | | |
| Total Scores | 20 | 13.90 (3.42) | 18.17 (1.42) | 4.3 (5.3, 3.3) | <0.001 (0.000004) |

*Non-parametric tests were used, SD - standard deviation, CI - confidence interval

correlation was present in the baseline scores but not in the post-debrief scores. We analysed the baseline scores further and found that in the unadjusted analysis, for a unit increase in the SOP scores for the anaesthesiologists, there was a corresponding reduction of 0.583 (CI: −0.926 to −0.240) ($P$ = 0.002) units in the POC score, which was statistically significant. Similarly, for the technician's score, the reduction was 0.313 (CI: −0.575 to −0.050) ($P$ = 0.021). On adjusting for the performance of the technicians, we noted that a unit increase in the SOP score for the anaesthesiologists was associated with a reduction of 0.539 (CI: −1.034 to −0.044) ($P$ = 0.034) units of POC, which was statistically significant [Table 2].

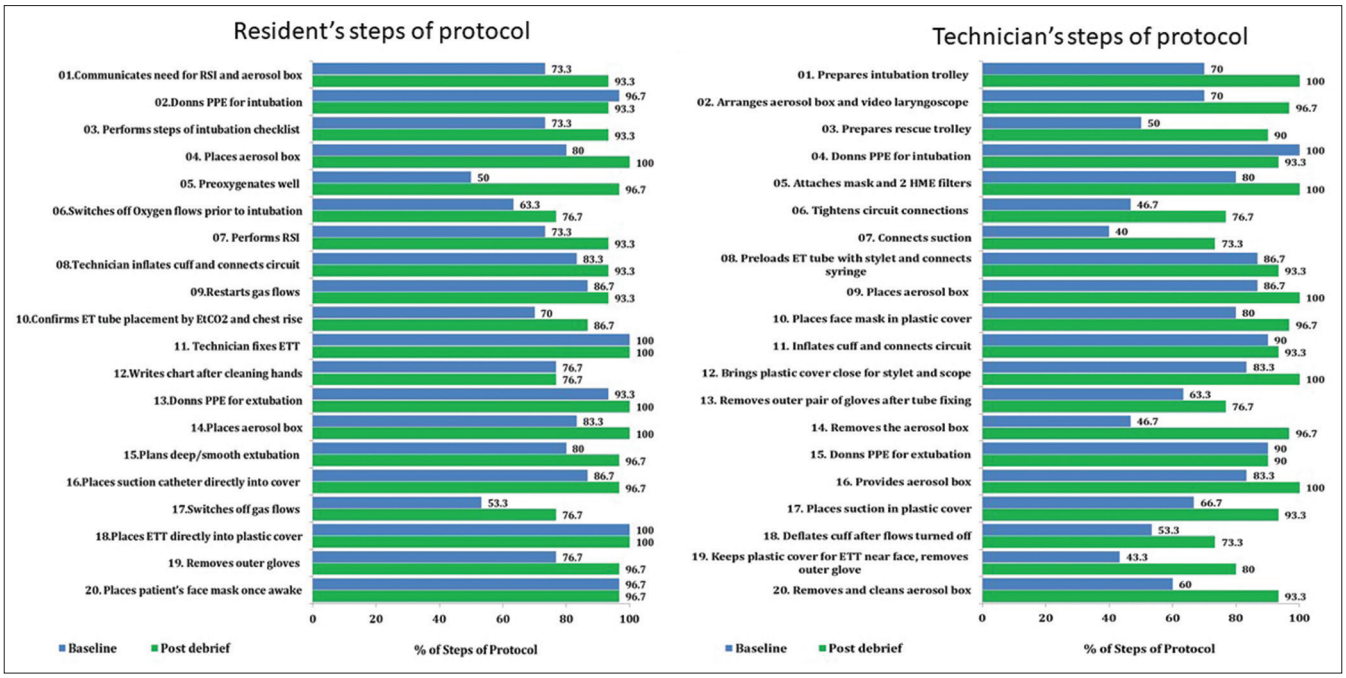


**Figure 3:** Steps of protocol by residents and technicians, baseline and post debrief

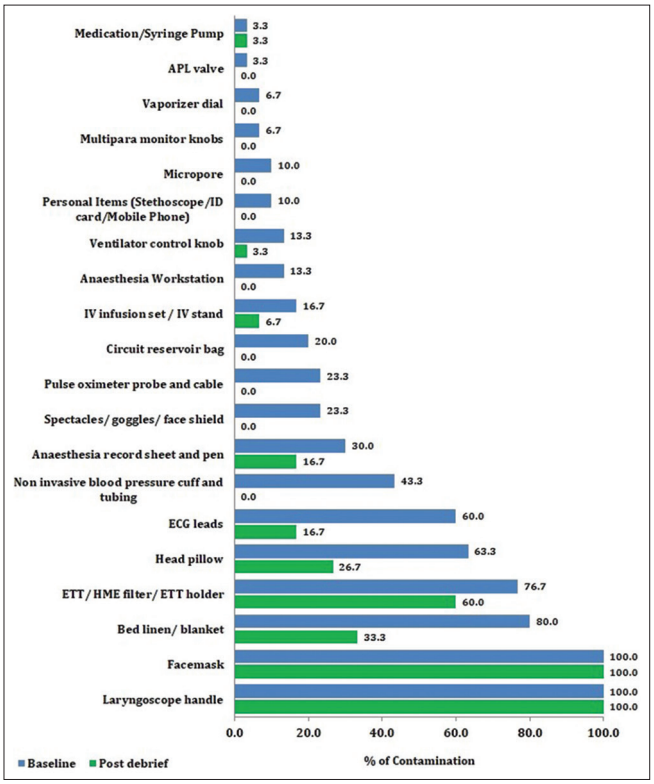


**Figure 4:** Points of contamination in baseline and post debrief

There was no correlation between the number of times the protocol video was watched and the baseline POC scores. The mean baseline POC score was 6.4 ± 1.6 in those who had viewed it more than once compared to 7.4 ± 2.9 in those who had seen it once or never.

**Table 2: Unadjusted and adjusted analysis for baseline SOP scores on POCs**

| | Regression Coefficient | 95% CI | *P* |
|---|---|---|---|
| Unadjusted analysis | | | |
| Residents | −0.583 | −0.926, −0.240 | 0.002 |
| Technicians | −0.313 | −0.575, −0.050 | 0.021 |
| Adjusted analysis | | | |
| Residents | −0.539 | −1.034, −0.044 | 0.034 |
| Technicians | −0.044 | −0.392, 0.304 | 0.798 |

SOPs - steps of protocol, POCs - points of contamination, CI - confidence interval

We obtained feedback from all participants regarding the simulation session [Annexure 3]. A majority of the participants 93.3% (56/60) felt that the use of the colour indicator helped them understand and remember the possible points of contamination during intubation and extubation. Almost all participants, that is, 96.6% (58/60), felt that the session improved their confidence in handling COVID-19 cases. When asked about the reasons for contamination in the real-life OR scenario, a majority of the participants, that is, 88.2% (52 out of 60), said their concerns of deterioration of the patient's clinical condition overrides the concerns of decreasing contamination. The other reasons for contamination included unavailability of equipment such as aerosol box and extra gloves (81.3%), difficulty in communication due to PPE (72.9%) and difficulty in adapting new protocols.

## DISCUSSION

The COVID-19 pandemic has prompted the revision of airway management protocols to minimise occupational risks.[11-14] Our study, which used a dye to simulate contamination during airway management, was devised in light of this new healthcare scenario. We found a significant decrease in the points of contamination and an increased adherence to protocols in the post-debrief session. The findings of our study agree with the current literature that simulation is an excellent practice-based learning tool for acquiring familiarity in high stake situations such as COVID- 19.[5,15-18] It has been invaluable in teaching ventilatory management,[6] introducing new protocols[5,15] and assessing OR preparedness for the COVID-19 patient.[16] Prior to the pandemic too, there have been simulation studies that focused on the reduction of contamination in the OR.[10,19] For specialities dealing with aerosol-generating procedures, these studies have taken on an urgent application.

Visualisation of contamination has been shown to be a powerful learning aid for infection control.[20] In our study, the colour indicator highlighted points of contamination and the average contamination rate reduced after the subjects visualised it for themselves, emphasising that 'seeing is believing'.

The residents had better baseline scores compared to the technicians. Familiarity with simulation training and access to accurate information on precautions to be taken in the COVID-19 scenario would have favoured the residents. The technicians being simulation naïve had lower baseline scores but had better improvement in mean scores at the post-debrief session.

The laryngoscope handle and the face mask were universally contaminated as found in the study by Porteous *et al*.;[19] thus, there was no difference in baseline and post-debrief. The bed linen and head pillow had high contamination rates because the contaminated face mask was placed on the linen instead of in a disposable bag. The endotracheal tube and HME filter were the next most common sites of contamination. This highlights the need to double glove and remove the outer pair of gloves soon after intubation as suggested by Birnbach *et al*.[10] The non-invasive blood pressure cuff and electrocardiograph electrodes were contaminated more at extubation, emphasising the need to remove the outer pair of contaminated gloves at extubation prior to shifting the patient.

We found a significant correlation between POCs and adherence to steps of protocol during the baseline simulation. In the post-debrief session, as POCs were low and the protocol was well adhered to, the correlation was not found to be significant. Further analysis of the baseline results after adjusting for the performance of technicians showed a significant correlation ($P = 0.034$) only for the performance of the residents. This points out that the anaesthesiologist, being the team leader, plays a major role in the extent of contamination caused.

The COVID-19 crisis has provoked an 'infodemic'- a situation of an overwhelming flood of information through health organisations and governments.[21] Thus, the department protocol video may have been viewed as one among the many protocol videos in circulation. We did not find a significant correlation between the number of times the video was viewed and the baseline simulation scores. The simulation helped our participants to consciously take note of each of the steps of protocol and each potential point of contamination. We infer that the video as a sole method of teaching new practices in the COVID scenario is not as effective as when combined with simulation. The majority (93.3%) of the study participants felt that the use of a colour indicator during the simulation helped them realise the extent of contamination that happens and convinced them of the need to adhere to the protocol.

A limitation of the study is that immediate recall could be one of the reasons for the good post-debrief scores. Ideally, a post-debrief session should be conducted a few weeks later. However, as this study was conducted when our country was seeing an uptick in the number of cases, we were unsure if we would get the same teams later. Another limitation is that we did not include a crisis scenario, which possibly explains the low baseline contamination. The aerosol box was used as part of the SOP as at the time of conducting this study, it was advocated as an adjunct to PPE.[22-24] Current emerging evidence on its use is conflicting.[25,26] Another limitation relevant to any simulation-based study is that it may not accurately reflect what occurs in actual clinical practice.

## CONCLUSION

The study concludes that with the use of a dye to simulate secretions in a low-fidelity mannequin, simulation training can be effectively done with locally available material, to create a safer working environment and improve confidence during the pandemic.

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### Conflicts of interest

There are no conflicts of interest.

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| Annexure 1: BASELINE and POST DEBRIEF Checklist for Anaesthesiologist | No: | |
|---|---|---|
| | **Baseline** | **Post debrief** |
| PREPARATION | | |
| Communicates plan of Rapid Sequence Intubation (RSI): | | |
| Donn full personnel protective equipment (PPE): | | |
| INTUBATION | | |
| Intubation checklist: Prepared circuit and tightened connections, 2 HME filters (one at patient end and one at expiratory end of circuit), $EtCO_2$ connected, suction ready (Yankauer/suction catheter), ET tube cuff checked, syringe for inflation attached to the cuff, stylet inserted in the tube. Disposable bags for mask, stylet and laryngoscope, suction catheter | | |
| Place aerosol box on patient's head end | | |
| Remove patient's surgical mask and keep it in a cover provided by the technician. Take face mask from technician for preoxygenation using the two-hand V-E technique making a tight seal with 100% $FiO_2$ and PEEP of 5 cm $H_2O$ for >3 min or $EtO_2$ >0.85. | | |
| Do not use nasal prongs for apnoeic oxygenation. | | |
| Oxygen flows switched off before taking off the face mask. | | |
| RSI using Macintosh/video laryngoscope. No ventilation during RSI. | | |
| Scope goes into disposable bag along with outer pair of gloves | | |
| Cuff inflated and circuit connected by the person administering drugs. | | |
| Gas flows started; ventilator mode selected by the person administering drugs. | | |
| ET tube placement confirmed by direct visualisation of cords, EtCO2 and chest rise. No auscultation. | | |
| ET tube fixation done by technician. | | |
| Write chart after cleaning hands | | |
| EXTUBATION | | |
| Donning of full PPE: | | |
| Place aerosol box. | | |
| Plan deep extubation preferably. Do suctioning in the deep plane to avoid cough reflex. If awake extubation is planned, give intravenous Lignocaine to suppress cough reflex. | | |
| Suction tube catheter/Yankauer placed into plastic cover after use without dripping secretions anywhere. If gloves are soiled, outer gloves removed, and extra pair worn. | | |
| Gas flows switched off, then cuff deflated, and tube removed. No recruitment given. | | |
| ET tube directly placed into disposable bag provided by technician who gives face mask also. | | |
| Remove outer pair of gloves. | | |
| Once patient is fully awake, obeying commands and maintaining saturation, switch to surgical mask (which was placed in a disposable bag) brought by the technician and then aerosol box removed. | | |
| BASELINE SCORE- | POST-DEBRIEF SCORE- | |

HME- heat and moisture exchanger, $EtCO_2$- end tidal carbon dioxide, ET- endotracheal, $FiO_2$- fraction of inspired oxygen, PEEP- positive end expiratory pressure, $EtO_2$- end tidal oxygen

| Annexure 2: BASELINE AND POST-DEBRIEF Checklist for Technicians | No: | |
|---|---|---|
| | **Baseline** | **Post debrief** |
| PREPARATION | | |
| Prepare intubation trolley: | | |
| a) Appropriate size Face mask | | |
| b) 2HME filters | | |
| c) ET tube (#7/#8) and syringe for cuff inflation | | |
| d) Stylet and bougie | | |
| e) Macintosh/Video laryngoscope | | |
| d) Suction: Yankauer/flexible catheter with tubing | | |
| e) Pre-cut ET fixation tapes | | |
| f) Micropore tape and scissors | | |
| g) Four disposable bags | | |
| h) Spare plastic sheets | | |
| i) Appropriate size oropharyngeal airway | | |
| j) Lignocaine jelly | | |
| h) Hand Sanitiser | | |
| i) Glove box (Score of 1 given if ≥9 points attained) | | |
| Checks with the anaesthesiologist regarding the need for aerosol box and video laryngoscope. | | |
| Prepare rescue trolley | | |
| a) LMA #3/#4 | | |
| b) Spare ET tubes | | |
| c) Front of neck access kit | | |
| d) Ambu bag (Score of 1 given if ≥3 points attained) | | |
| Donn full PPE: | | |
| INTUBATION | | |
| Attaches face mask, HME filter; one at patient end and one at expiratory end of the machine. $EtCO_2$ connected | | |
| Confirm that circuit is tight at all connections by rotating it clockwise. | | |
| Yankauer/Flexible suction connected. | | |
| Preload ET tube with stylet, cuff checked, and syringe connected with cuff for inflation. | | |
| Place the aerosol box. | | |
| Face mask placed in the disposable bag. | | |
| Provide ET tube with stylet. | | |
| Once tube is in, remove the stylet and place in a disposable bag, and inflate the cuff. | | |
| Bring disposable bag close to take the VL/Macintosh laryngoscope in it directly. | | |
| Remove outer pair of gloves after securing the tube at stated depth. | | |
| Remove the aerosol box and cleans it inside before next use. | | |
| EXTUBATION | | |
| Donns full PPE | | |
| Provide aerosol box. | | |
| Provide suction: Yankauer/flexible catheter and collect it in a disposable bag directly without spillage of secretions | | |
| Deflate cuff only after the flows and ventilator is off. | | |
| Keep disposable bag near the face of the patient to take the ET tube as soon as it is removed. Remove outer pair of gloves. | | |
| Provide face mask to the anaesthetist. Remove aerosol box when asked for and cleans the inside. | | |
| BASELINE SCORE- | | POST-DEBRIEF SCORE- |

HME- heat and moisture exchanger, ET- endotracheal, LMA-laryngeal mask airway, PPE- personnel protective equipment, $EtCO_2$- end-tidal carbon dioxide, VL- video laryngoscope

**Annexure 3: FEEDBACK SHEET**

Designation: ..... Date: .....

| CRITERIA | Strongly agree (5) | Agree (4) | Neutral (3) | Disagree (2) | Strongly disagree (1) |
|---|---|---|---|---|---|
| Feedback regarding the simulation | | | | | |
| 1. Simulation session was useful in the current scenario. | | | | | |
| 2. Duration of training session was adequate. | | | | | |
| 3. Content was well organized and well presented. | | | | | |
| 4. This session improved your confidence in handling suspected COVID cases | | | | | |
| 5. You know various points of contamination and can prevent it during routine handling of cases. | | | | | |
| 6. The red colour indicator helped you understand and remember the possible points of contamination. | | | | | |
| What do you feel are the reasons for contamination in the operating room? | | | | | |
| 1. Lack of equipment or distant location of equipment and supplies leads to contamination. | | | | | |
| 2. Existing practices makes it difficult to adapt to the new protocols | | | | | |
| 3. Concerns/fear of deterioration of patient's clinical condition (e.g. desaturation, hypotension) overrides the concerns of decreasing contamination | | | | | |
| 4. Discomfort/difficulty in communication due to personnel protective equipment (PPE) comes in the way of trying to decrease contamination | | | | | |
| 5. Time pressure is often a reason for compromising on steps to decrease contamination | | | | | |

How many times did you view the video prior to the baseline simulation?

Any other comments: