Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Managing surgical patients with a COVID-19 infection in the operating room: An experience from Indonesia

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ABSTRACT

Background: The Coronavirus and the COVID-19 pandemic in 2020 have significantly impacted hospital care, including surgery practice. Hospitals must balance patient care, staff safety, resource availability, and medical ethics. Differences in community infection trends, national policies, availability of resources and technology, plus local circumstances may make uniform management impossible globally. This paper described the practical workflow of emergency COVID-19 surgery in a tertiary referral national hospital in Indonesia.
Method: This study focused on the process of preparation for COVID-19 surgery from March 2020-March 2021. We also described the available facilities in terms of equipment and human resources.
Results: Steps of COVID-19 surgery preparations were described, such as the setup of general and infectious triage in the emergency department, development of preoperative screening protocol for COVID-19, designation of a specialized COVID-19 operating room and surgical staff, changes in preoperative surgery and anesthesia workflow, development of checklists and postoperative monitoring on staff health.
Conclusions: Changes in the workflow are essential during the pandemic for safe surgery. These changes require a multidisciplinary approach, communication, and a continued willingness to adapt. We recommend local adaptation of our general workflow for emergency surgery during an epidemic or pandemic.

1. Background

WHO announced a severe acute respiratory syndrome pandemic caused by the Coronavirus type 2 (SARS-CoV-2) virus and its known disease, COVID-19, in March 2020. From January 4th, 2021, it was reported that 83,910,386 confirmed cases of COVID-19, including 1839,660 deaths.[1] During the same period, Indonesia reported 765,350 confirmed cases of COVID-19 with 22,734 deaths. During this time, Indonesia has the highest caseload in South East Asia.[2] As more and more people became infected in Indonesia, our hospital, a national referral hospital situated in the most densely populated island, received referrals and local patients suspected of having the disease, with some requiring emergency surgery.

SARS-CoV-2 spreads via droplets and possibly aerosol, which is produced frequently in medical procedures such as intubation, ventilation, and suction. It is unavoidable that aerosol-generating medical procedures mentioned earlier are done in the operating room.[3-5] Another issue in the operating room is the possibility of air and surface contamination in the operating room. Studies reported that the SARS-CoV-2 virus was viable in aerosols with a half-life of 1.1 to 1.2 h and was still detected at the 3-hour mark of experiment time with a reduction in an infectious titer. The same study found that the most prolonged virus viability was stainless steel and plastic, with an estimated median half-life of approximately 5.6 h on stainless steel and 6.8 h on plastic.[3] These findings were alarming for surgery since most surfaces in the operating room were made of plastic, and most instruments have steel elements.

Since SARS-CoV-2 virus infection also depends strongly on individuals' human traffic and closeness, the operating room becomes a high-risk zone for transmission. A modern operating room is similar to a mega airport that involves a high movement of people such as medical and non-medical staff, patients, and family members. Hence, the operating room could quickly become the source of a hospital outbreak with the possibility of infection for staff and the local community. Evidence supports the relation between human traffic in the operating room, airborne bacteria, and subsequent surgical site infection in surgical

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procedures.[6,7]

Concise and clear steps for infection control, workflow adjustments, and other technical guidance must be made to ensure the patients, staff, and community's safety. However, since political logistics, funding, and community disease patterns may differ from hospital to hospital, a uniform strategy may not apply to all scenarios.

Although WHO clearly outlined the required protocol to manage hospitals during the pandemic, limitations in a developing country such as ours may appear in different levels of management. Crucial to the pandemic were problems in testing capability such as test availability, capacity, and speed of result that significantly influence decisions in surgery.[3,5] There was also a limitation in the availability of standard operating room for infectious surgery nationwide, and many cases had to be referred to a referral hospital which adds a centralized burden during the early period of the pandemic on the availability of personal protection equipment (PPE), reduce the capacity of hospital beds and risk of transmission to hospital staff. Both WHO and the Indonesian Ministry of Health did not specify regulations for surgery during the pandemic. More time was needed to adopt general health regulations for surgery requirements.[4,5]

When this paper was written, we had performed 152 suspected and or confirmed COVID-19 surgeries from March 2020 to early March 2021. We aim to describe the policy, workflow, and practical execution of COVID-19 surgery in a tertiary referral hospital in Indonesia.

2. Method

This study was done between May 2020 to May 2021 in a tertiary referral and teaching hospital in Indonesia. Our hospital review board considered this study a quality improvement project and not considered human research, hence IRB waived consent requirements. The observations and data collected in this study are connected to our co-study regarding surgical patients with COVID-19 that had been reviewed and was given ethical clearance or institution's review board (IRB) number LB.02.01/X.6.5/161/2020. Data from our co-study is not presented in this paper since this paper focused solely on the quality improvement reports. The standards for quality reporting Excellence (SQUIRE) was used as a general guideline on the writing of this report.

3. Results

3.1. Preoperative phase

3.1.1. General preparation

The Indonesian Ministry of Health reported the first case of COVID-19 in Indonesia on March 2nd' 2020, and as a result, our hospital reduced elective surgery capacity to 20%, and only emergency surgery continued in standard capacity.[2,5] During this early time, a COVID-19 inpatient zone was prepared with advanced staging scenarios in place[4,5] (Fig. 1). In March 2020, scenario two was initiated with more isolation and ICU beds. Due to the high number of caseloads, scenario three was commenced in December 2020, but our hospital has never had to open maximum capacity with at 1000 beds with 45 ICU beds.

This designated restricted red zone –known later as the Kemuning COVID-19 Zone- was an enhanced on-site facility that was an extension of our existing isolation unit, once designed to house previous emerging and re-emerging disease patients such as Avian flu, Swine flu, SARS, and currently the multi-drug resistant tuberculosis patients. Previously, the second to sixth floors of the Kemuning isolation zone was our surgical ward. By April 2020, we have transferred all surgical patients to other wards in our hospital or our partner hospital in the city.

During the early months of the pandemic, testing equipment for SARS-COV-2 was not yet available, and testing reagents were pooled in several national laboratories; hence final antigen testing was impossible. We had to send our laboratory samples for real-time reverse transcription-polymerase chain reaction (RT PCR) of SARS-CoV-2 to the West Java district laboratory. By late April 2020, our hospital was equipped with on-site PCR testing as a gold standard of diagnosis and a designated computed topography for COVID-19 for clinical analysis.[4,5] Although testing was available, we later learned that in the setting of emergency surgery, only having a testing capacity was not enough since result time was an essential determinant of decision making in surgery.

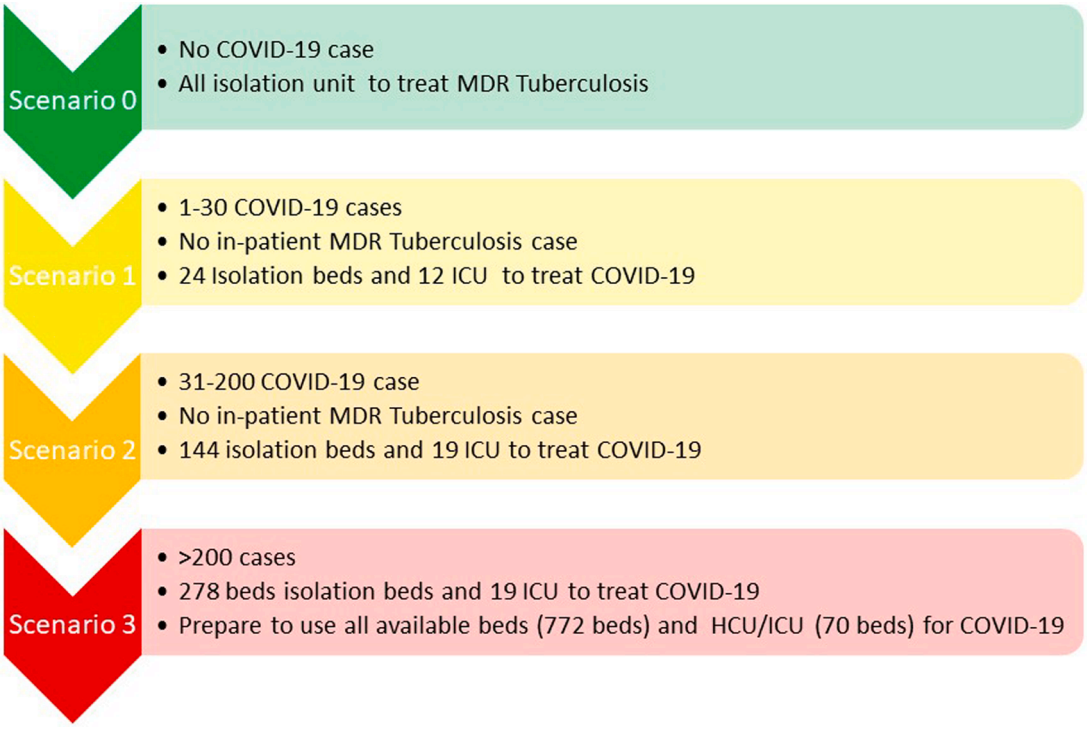

Fig. 1. Summary of Hospital Preparation Scenarios for COVID-19 Preparedness
MDR : Multi Drug Resistant ; ICU : Intensive Care Unit ; HCU : High Care Unit.

Our hospital met logistic problems during the early month of the pandemic with the low availability of PPE. PPE was crucial in the care of COVID-19 patients and surgery in general during the pandemic. Since our hospital was a national hospital, all of our logistics were supplied by the Indonesian Ministry of Health. However, since the demand was higher than supply, our hospital dynamically worked with the local organization and the West Java people to resolve this problem. We received multiple donations of PPE from the community, and by July 2020, the Indonesian Ministry of Health was able to maintain a stable chain of PPE supply but community participation is still a part of our day-to-day practice pandemic. As was also reported from the United Kingdom and the United States, grassroots movements to PPE supply with community involvement is a possible alternative during a health crisis.[8,9]

3.1.2. Staff preparation

During the early weeks of the pandemic, the hospital's Human Resource Department issued a performance health evaluation to all department heads. The instruction was to classify which staff members could not carry out direct care for patients with suspected or confirmed COVID-19. According to the Indonesia Ministry of Health protocol, the exclusion criteria included staff above 60 years old, pregnant, immunocompromised, severely obese, and other criteria. Those who met the exclusion criteria were redirected for support in routine health care services.[4-5]

The *panitia pencegahan dan pengendalian infeksi rumah sakit* (PPI) or the hospital prevention and infection control team provided information about PPE use in each unit, the flow of suspected or confirmed COVID-19 patients, and the preparation strategies for facilities and infrastructure in case of a spike in cases. The information was comprehensively provided to all staff through training posters, round checks, and demonstration videos posted on the hospital's YouTube channel called "Kanal RSHS" (links provided at the end of the paper).

The PPE for staff working in the COVID-19 OR was a fitted N-95 mask, goggles, a face shield, a cap, a gown, shoe covers, boots, boot covers, and a hazmat suit. Our hospital does not provide powered air-purifying respirators (PAPR), so it was deemed crucial that an appropriate N95 mask size was tested utilizing a "fit test" carried out by the hospital infection prevention and control team, and these tests were carried out on our staff in the early days of the pandemic.

The anesthesia and intensive care department had three additional work areas to cover: the COVID-OR, COVID-19 high care/intensive care, and COVID-19 emergency room unit. During this period, anaesthesiologists play a significant role in the in-hospital COVID-19 management, and policies adapted from the WHO or Kemenkes Indonesia guidelines were set to maintain our staff's general well-being. First, the general policy was the cessation of all scientific teaching and administering examinations where groups of people would gather - all of which were moved to online platforms. All residents and consultants were given a day off after COVID-19 care. A "bubble" system was created in which one team would have zero to limited contact with other staff outside of their bubble group. An internal surveillance team was set up to monitor daily staff health and urgently seek and trace if a possible infection occurred. All staff was discouraged from coming to work if they felt feverish or had influenza-like syndromes, or were generally unwell.[4,5]

By February 2021, all anesthesia and surgical team in our hospital had received the second dose of the COVID-19 vaccine, and future observations on the effect of this vaccine on the infection rate among health care workers would be an exciting topic to discuss in the future.

3.1.3. National referral procedure

Our operating room received referred and locally sourced emergency surgical cases suspected or confirmed COVID-19 from our emergency unit. The referred cases were consulted to our hospital via the Indonesian Ministry of Health national referral system known as the *sistem informasi rujukan terintegrasi* (Sisrute) or translated as '*The integrated referral information system*,' accessed from the web address https://sisrute.kemkes.go.id/baru/index.php. The Sisrute system collected information regarding the patient's basic demography, symptoms, laboratory, and imaging results, which would then be evaluated remotely by the emerging and re-emerging infection team or better known as the Pinere team.

The Pinere team would approve or reject a consultation based on the availability of postoperative beds and the requirements. Among the board of consultants in the Pinere team, an appointed surgeon, anaesthesiologist, and obstetrician were included in catering to the need for surgical cases. Surgical patients from our emergency unit were consulted to our operating room via the hospital information system after they had been evaluated by the Pinere team.[3,5]

Upon approval, the district hospitals transported their patients according to the national standard of patient transport guidelines to our hospital. Our isolation emergency unit received suspected and confirmed cases in a separate wing from our regular emergency room complex.

3.1.4. Preoperative phase

A uniform general screening for COVID-19 was conducted in the emergency triage during the preoperative period using a standard questionnaire. Patients who fulfilled the criteria for suspected COVID-19 or were a confirmed case with a positive PCR result were isolated in a specified isolation wing of the emergency unit.[3,5] Regarding surgery, two possible scenarios surfaced: whether the patient was a surgical patient who needed COVID-19 screening for surgery or the patient was a medical case with a suspected/ confirmed COVID-19 case later requires surgery. The latter scenario was found to be uncommon in our center.

The screening procedure did not change during the pandemic, but the diagnostic options evolve quickly by the end of 2020. As anesthesia and surgery involve high-risk aerosol procedure and principles of social distancing, surgical mask use and ventilation were challenging to maintain in the operating room; all surgical patient was required to be consulted to the in-house Pinere team before surgery. Besides the standard questionnaire, a series of blood work, chest X-ray, rapid antibody and or antigen test, PCR testing, and chest scan was required. The laboratory and radiological examination to determine patients' COVID-19 status evolved due to the innovations developed during the pandemic and available new technologies in our center. (**Fig. 2**)

Since no testing was available on-site during the early months, the screening for COVID-19 relies heavily on findings through anamnesis, contact tracing, physical examination, blood work such as leucocyte, total lymphocyte, and neutrophil-lymphocyte ratio, chest radiograph image of bronchopneumonia, and rapid antibody testing. The findings mentioned had only 40–60% sensitivity or specificity to diagnose COVID-19 than PCR. A significant proportion of COVID-19 patients was also asymptomatic during admission, and false-negative classification of a patient's COVID-19 status before surgery was and still is possible.[10-12] Limitations on working hours of the laboratory and time to result also impacted surgical care. As a result, our hospital saw an increase in surgical demand for PPE, increased use of negative pressure chamber operating room, and requirements for postoperative isolation ward, which resulted in inefficiency both in resources and general cost.

According to our policy, only two surgical cases did not require preoperative COVID-19 screening, which was life-threatening hemorrhages and fetus distress in which surgery would proceed using the required level 3 personnel protection equipment (PPE). The anesthetic visit was done via video call for anamnesis to minimize exposure and limit the use of valued PPE while laboratory and radiological examinations are available online in the hospital information system (HIS).

3.2. COVID-19 operating room and team

3.2.1. COVID-19 operating room

Positive pressure is the typical approach in the operating room (OR)

Stages	Stage 1 (March –April 2020)	Stage 2 (April 2020-August 2020)	Stage 3 (September- December 2020)	Stage 4 (January 2021-currently)
In-House PCR testing available ?	No	Yes	Yes	Yes
Time to PCR Result	7 days	3 days	12-18 hours	1-2 hours
Timing of test	Only working days Only working hours	Only working days Only working hours	Only working days Only working hours	24 hours, 7 days a week
Other Test Available	RSHS COVID-19 score Rapid antibody test	RSHS COVID-19 score Rapid antibody test	RSHS COVID-19 score Rapid antibody test Thorax CT-Scan	Rapid antibody test CT- Thorax Rapid antigen testing
Policy for Emergency Case	No preop testing needed Proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward	No preop testing needed Proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward	No preop testing needed Proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward	Proceed with level 3 PPE, and negative pressure chamber Intraoperative swab is taken and wait for results to determine post op unit
Policy for Urgent Case	Either a suspicious RSHS COVID-19 score **OR** positive rapid antibody test **OR** high risk aerosol surgery **AND** confirmed by Pinere then surgery proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward	Either a suspicious RSHS COVID-19 score **OR** positive rapid antibody test **OR** high risk aerosol surgery **AND** confirmed by Pinere then surgery proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward	If possible to delay, await PCR screening results. If not possible to delay, either a suspicious RSHS COVID-19 score **OR** positive rapid antibody test **OR** suspicious Thorax CT-Scan **OR** high risk aerosol surgery **AND** confirmed by Pinere then surgery proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward.	Preop PCR screening is needed for all urgent surgery. If, PCR is positive and surgery can not be delayed, surgery proceed with level 3 PPE, negative pressure chamber and post op to COVID-19 ward
Policy for Elective Case	Reschedule until PCR result is negative	Reschedule until PCR result is negative	Reschedule until PCR result is negative	Reschedule until PCR result is negative

Fig. 2. Evolution of Preoperative COVID-19 Screening for Emergency Surgery.
RSHS : Dr Hasan Sadikin National Referral Hospital; PPE: personal protection equipment; CT-Scan : computerized topography; PCR: polymerase chain reaction; Pinere : emerging and re-emerging infectious disease team.

to prevent the circulation of pathogens that could contaminate an open wound. However, this protocol poses a risk to staff and other patients during the pandemic since aerosol-generating procedures are conducted. In concordance with several recommendations, negative pressure ORs could minimize infection risk. A high air exchange cycle rate ($\geq$ 25 cycles/h) is also maintained to reduce ORs' viral load. This negative chamber was concordant with many guidelines and was also adapted during the SARS outbreak in Singapore, Taiwan, and Canada.[13,15-20]

The specialized COVID-19 operating room - 301 infectious wing – consisted of 4 operating rooms, but only one room was equipped with negative pressure and an anteroom. This wing was once used to host

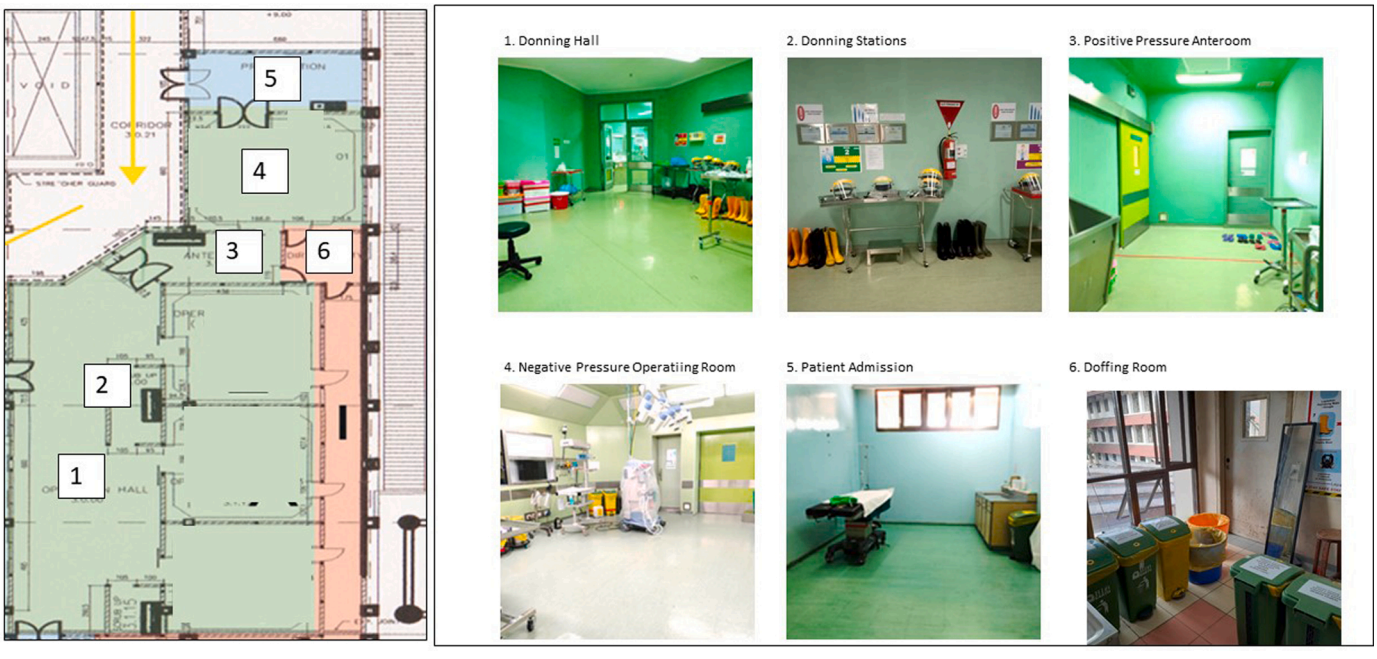

Fig. 3. Diagram of COVID-19 infectious Surgical Operating Room.

surgery for multi-resistant tuberculosis patients. The 301 was separated into five areas: the patient admission, the surgical room, the anteroom, the doffing room, and the dressing hall (Fig. 3). To further reduce contamination, the patient entrance access was separated from the usual route, and the hallway connecting the 301 to our central operating room was sealed. Strict staff mobilization in and out of the area was ensured to reduce footwork.[6,7,13-15] As surgery for COVID-19 patients increased during the last period of 2020, an emergency scenario was also set up for if more than one operating room is needed simultaneously. As was done in Hong Kong and Singapore during the SARS outbreak, the other three operating rooms could be modified into a negative-pressure room by attaching exhaust fans with high-efficiency particulate air filters to windows leading to the outside.[13-18]

Room 301 as the operating room was monitored using two CCTV cameras connected to a nurses' station's control desk. CCTV and mobile phones were an essential part of team communication in COVID-19 surgery. The room was also equipped with one landline phone and one set of handy talkies for communication.

The central operating room created an activation protocol for COVID-19 surgery that included team activation, surgical and anesthesia equipment setting, surgical donning and doffing procedures, and patient transport. An additional anesthesiologist and surgical nurses were called in for COVID-19 surgery during work hours, but the limitation in human resources caused this system not to be available during night and weekend shifts. Consequently, other emergency surgery had to be postponed during COVID-19 surgery during the night and weekend. Roles for COVID-19 surgery were the attending anesthesiologist, anesthesiology resident, anesthesia nurse, attending surgeon, surgery residents, scrub nurse, in-room circulating nurse, and two out-of-room circulating nurses or "runners," which consisted of one anesthetic nurse and one surgical nurse.

Since more time is needed to prepare for COVID-19 surgery, especially on room settings and personal protection equipment donning, the COVID-19 surgery was separated into several checklists (**supplementary 1**). The essential checklist was implemented daily regardless of whether any COVID-19 surgery was planned for that day. The checklist was divided into the surgical checklist, anesthesia checklist, and general checklist. Some ideas for the checklist came from general guidelines such as by the American Association of Anaesthesiologists (ASA), and some details were developed from local needs and recently published guidelines. [16–26]

3.3. COVID-19 or preparation

When a COVID-19 surgery is planned, the surgeon enters the central operating room (COT) plan via the hospital information system (HIS). Upon receiving the HIS request, the nurse-in-charge of the operating room will notify the anesthesiologist on-site and the COVID-19 surgical team. A neonatologist will be notified if a Cesarean section was the planned surgery. The nurse-in-charge would also confirm a post-operative care room's availability in the red zone.

The pharmacy prepared drugs and disposable items needed for surgery and anesthesia in ready-to-use packages using a checklist. The pharmacy also prepared packages of disposable PPE and labeled each package with the specific roles on the team. The drug package is delivered to the 301 operating room, and the PPE packages are sent to the donning hall to be paired with labeled face shields, goggles, and boots in designated donning stations.

An anesthesia machine, monitors, surgical table accessories, and video laryngoscope were covered with a pre-cut plastic wrap to reduce surface contamination (Fig. 4). The wrapping was performed to reduce surface contamination. Studies proved that droplets/ aerosols from SARS-CoV-2 could be detected on all types of surfaces and in the air within 4 m of the patient with 24–72 h of survival period on surfaces.[3,13,15,20] Wrapping procedure allowed for easy disposal and more surface protection.

Fig. 4. Anesthesia Setup for OVID-19 Surgery.

Specifics for anesthesia were high efficacy performance air (HEPA) filters on the patients' end and machine entry port of the anesthesia machine while the emergency trolley, defibrillator, and ultrasonography (USG) equipment were set in the anteroom to reduce equipment spoilage. Anesthesia drugs were prepared in stark-labeled syringes for easy identification. The surgical nurse prepared sterile instruments, gauze packs, sutures, an electrosurgical unit (ESU), and other equipment and the circulating nurse will distribute labeled designated googles, headshields, and boots to the donning stations with the pharmacy's PPE packs. The circulating team would also spray anti-fog sprays or soap sprays to the goggles and face shields to reduce the fogging.

As the team has assembled, the time-out checklist was started. A review of the patient's data, the surgical site, potential complications, and other essential information was laid out. The nurse in charge would then read the safety protocol inside the room, donning and doffing procedure, and the post-op staff observations procedure (Fig. 5).

The team will proceed with the donning routine, and the nurse in charge will alert the emergency isolation room to begin patient transport. The donning stations are equipped with a donning diagram, a donning checklist with an assistant named "*the buddy system*" to monitor the quality of the donning process. The runner would label each staff for easy identification using a bold marker on their backs and fronts since communication may hinder the operating room.

3.4. Patient transport

When the patient comes from the emergency unit, the patient would be transported using the infectious elevator from the first floor to the third floor where the 301 is situated, but if the patient were coming from the Kemuning zone, then an ambulance would be needed since the 301 was on a separate complex from the Kemuning zone.

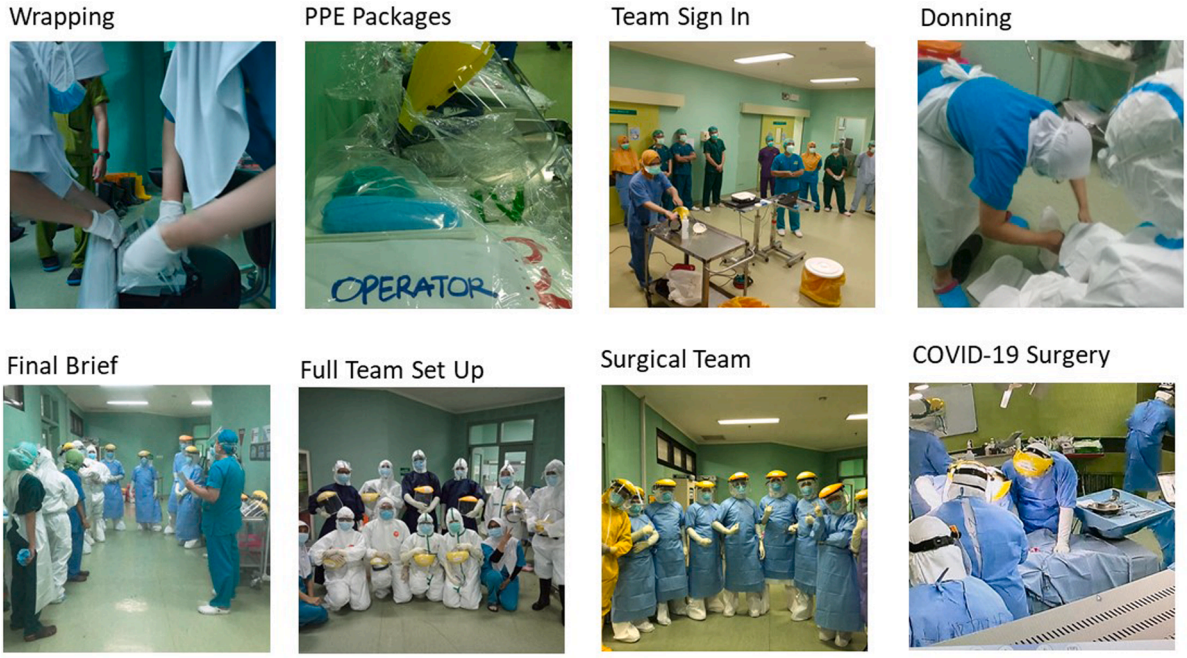

Fig. 5. COVID-19 Surgical Team Preoperative Preparations.

These steps are taken as our hospital policy dictates strong segregation between clean and contaminated zones in our hospital. Suspected or confirmed COVID-19 cases cannot travel in our hallways, and an ambulance transportation protocol is chosen as the method to transport our patients. The study has shown that zonation and maintaining separation between zones was critical in managing the SARS outbreak in Taiwan, and the same principles have been applied here.[18]

The patient is transported from the first floor to the third floor using a particular unit inside a full body-aerosol box with a fully PPE-equipped team from the emergency room, accompanied by decontamination personnel with a sprayer. No family member was allowed to accompany the patient to the operating room unless the patient was a child, whereby a parent with a surgical mask and face shield is requested to assist.

3.5. Anesthesia and surgery for the COVID-19 patient

Upon arrival in 301, the patient changes into a surgical gown attended by the anesthesiologist, anesthesia nurse and circulating nurse. The patient would then gargle with povidone-iodine 1% solution inside the aerosol box. Studies have shown that povidone-iodine gargle and nasal spray may reduce SARS-CoV-2 colonization in the upper airway.[24] All paperwork, such as for sign-in and check-in procedures, are conducted via telephone/handy talky to the nurse in charge, and no paperwork or writing was allowed in 301.

The patient was then transferred to the surgical room using the "one gate" system, where only one door was opened between each area to maintain room pressure and zonation. The one-gate system was maintained during the entire anesthesia and surgical procedure. The anesthesia induction was performed with only the anesthesia team and a circulating nurse in the operating room.

Standard anesthesia monitoring was used, such as saturation, electrocardiography, blood pressure, temperature, and end-tidal CO_2($ETCO_2$). An invasive monitoring device would be considered on a case-by-case basis. Whenever possible, regional anesthesia or peripheral nerve block was the chosen technique to avoid airway manipulation. The patient continues to use a surgical mask, and if oxygenation is needed via nasal canulae or masks, it would be inserted below the surgical mask.[15,18-26]

Several principles in general anesthesia were used primarily related to aerosol production. Some of those principles were that the oxygen flow should be turned off before any exchange to other oxygen delivery systems was made, two-hand tight-mask seal technique for preoxygenation or ventilation, preoxygenation with rapid sequence intubation (RSI) or small tidal volume ventilation if RSI is not possible. We also mandate the use of video laryngoscopy, endotracheal cuff ballooning before ventilation, endotracheal tube use rather than laryngeal mask airway, use of $ETCO_2$ to confirm tube placement and closed system suctioning.[15-26]

The surgeon and surgical team entered the operating room after induction of anesthesia, already in their sterile gowns over the level 3 PPE. During surgery, two nurses, called runners, assist surgery with added equipment needs and the guide team for disrobing and shower protocols. If additional instruments or drugs are needed, the runner placed them on a trolley in the anteroom. The circulating nurse would come out to the anteroom to take the item while maintaining the "one-gate" system and no contact between the person inside and outside the COVID-OR.

Since no post-anesthesia care unit is available for COVID-19 patients, the anesthesia team evaluates the patient post-operatively using the standard Aldrete score as a dismission criterion to the COVID-19 zone while the patient is still in the operating room. The anesthesia team handed over the patient to the inpatient team at the patient admission area. Meanwhile, the team starts the disrobing procedure one by one in the disrobing area guided by a runner utilizing a loudspeaker, a doffing checklist and a guide picture (**Figure 6; supplementary 2**).

3.6. General cleaning

The cleaning staff entered the 301 wearing PPE suits with surgical masks and long cleaning gloves at a minimum of 15 min after surgery to allow possible aerosol to clear from the surrounding environment. The procedure starts with the disposal of all plastic wraps from the various equipment, disposal of all waste, and the management of dirty linen. The anesthetic breathing circuit, airway apparatus, and soda-lime were all disposed. All surfaces were then cleaned from spoilage using water and disinfectant. The surface was also dried, and second disinfection with a 70% alcohol or 0.5% chlorine solution was performed. The last cleaning stage was a dry mist procedure for 30–40 min using either an H_2O_2

booster or chlorine dioxide [3, 15,17,23]

All waste from COVID-19 surgery was considered contagious and was separated into a yellow marked plastic hazard bag with COVID-19 markings and taken via a "dirty" corridor to the disposal unit. The surgical instruments are taken to the doffing area and a team from the central sterilizing unit would seal them for relocation in a particular travel lorry. The equipment was taken to the sterilizing unit where the cleaning process was conducted, separated from other hospital instruments. After 30 min to 2 h of rest after the dry mist, the room is ready to be used again. The entire cleaning procedure takes around 4 h.

Staff showered post-operatively in a designated shower area with soap containing chlorhexidine solution, gargle with 1% povidone-iodine and apply the nasal spray. The nurse in charge recorded staff data and submitted the data to the infection prevention team in the hospital. All team members must perform two temperature checks per day in an online form and report immediately if any symptoms occur for further evaluation in concordance with the WHO guideline.[4]

4.Discussion

Our hospital has conducted close to 150 suspected and confirmed COVID-19 surgeries from March 2020 to March 2021. As seen with our experience, many other centers worldwide had to use a multidisciplinary approach and changed their surgery workflow to cater to specific needs during the pandemic. As Italy became an epicenter of the early outbreak in Europe, an Italian hospital reported massive reorganization efforts for emergency surgery similar to our experiences such as creating an infectious triage in the emergency, designating a specific negative pressure operating room COVID-19, and full PPE for surgery.[27] Another report from a Singaporean hospital reported the same rigorous preparation for COVID-19 surgery with several differences with our experience: PAPR, avoidance of staff cross contamination by dedicating personnel only for COVID-19 surgery, and the ability to perform simulations beforehand with all of their staff. These steps in theory, match multiple guidelines but were not applicable in our center due to budget and human resource constraints.[15]

The critical issue for surgery on COVID-19 patients was the additional time needed for the patient to get the surgery. In our experience, the significant delay was due to the screening and diagnostic procedure for COVID-19. The availability and time-to-results of antigen testing became critical in COVID-19 diagnosis. Since a more advanced technological-based examination is needed - the PCR- then in developing countries where this technology may not be available readily, delays were unavoidable (Fig. 1). In our center in the early weeks of the pandemic, the surgical decision was so late due to screening protocols that two patients died before getting their surgery.

CT-scan was the recommended tool for rapid SARS-CoV-2 diagnosis as a metanalysis concluded that the detection of COVID-19 chest CT imaging is very high among symptomatic individuals at high risk with up to 80% sensitivity in asymptomatic patients to diagnose COVID-19. However, it was unavailable in our center at the beginning of 2020. A false negative on a CT- scan is also problematic since reports from the Italian hospital above that mandate a preoperative screening chest CT scan instead of the routine chest x-ray for surgery shows three percent of the surgical candidates with non-respiratory symptoms which had a negative chest CT scan finally had a positive nasopharyngeal swab.[27] The same problem in diagnosis COVID-19 compared to the timing of surgery was also reported from ground zero in Wuhan.[28,29] Similar to our policy, level 3 protection and negative pressure operating rooms were used religiously and although safe, may not be the most efficient approach.

The effect level 3 PPE for emergency surgery had an unavoidable toll on our team's general health and clinical capability even for performing simple and routine procedures. Since surgery was a meticulous process and duration more often was longer than our standard 3–4 h PPE time limit, staff reported dizziness, heat stress, and reduced concentration during surgery. The study has proven that after wearing PPE there is considerable thermal stress ultimately affecting human performance, which increases physical stress and may lead to a decrement in concentration.[30-31]

Two urgent innovation is needed regarding diagnostic tool and suits. Research into suits that are lighter, cooler, have a separate oxygen supply, and are at an affordable price is needed urgently as the pandemic continues to be an issue for the immediate future.[30-31]

As for quick, sensitive, and specific antigen testing for SARS-CoV-2 which is critical for surgery, a possible approach is recommended by our center. In 2021, our hospital used the already available GeneXpert MTB/RIF molecular platform (Xpert; Cepheid, Sunnyvale, CA, USA) for SARS-CoV-2 detection which provided results within 45 min. The optimization of already owned technologies, such as the GeneXpert MTB/RIF platform, requires a minimum number of trained staff and less infrastructure and equipment when compared with classic real-time PCR. Reports from our hospital and Madagascar show that optimizing the GeneXpert MTB/RIF platform for the surveillance of SARS-CoV-2 in low-income and middle-income countries is relevant and achievable should be considered in settings with difficult access to laboratories and an already existing GeneXpert MTB/RIF network.[32]

Another delay was the availability of a postoperative room since our hospital also manages nonsurgical COVID-19. At the highest peak of COVID-19 in our province, December to January 2021, room availability was scarce even when our Kemuning zone capability was maximized at 100%. This issue became complicated when the patient surgical COVID-19 patient required high care or intensive care postoperatively since the availability was even lower.[2,4]

Delays were also unavoidable as surgery preparation for COVID-19 was complex. It is crucial that during this pandemic, the operating room develop checklists, perform simulation, do evaluation and adjustments routinely.[15,21-27] The use of the checklist and workflows has increased our capacity in curving this delay and we have been able to shorten our preparation time to 40 min. At the highest peak of our community infection rate, the potential of a second COVID-19 surgery being planned while the first one was being conducted or the cleaning procedure had not finished was highlighted. As this paper was being written, our hospital prepared an emergency scenario including the closure of an entire surgical wing or the renovation of a second COVID-19 operating room.

Lastly, although there was no proven record of intra-operative infection among our staff, reports of mental stress due to fear of being infected remained high. Studies showed that health care workers are 23 times more at risk of getting COVID-19, which is the basis for rational fear among health care workers. As mitigation steps, we perform the post-surgery evaluation in an online setting on a case-by-case basis to allow team members to communicate their fears and input to the system. Our hospital has also taken significant safety steps such as guaranteeing PPE availability, supporting routine tracing, and providing swabs for the staff. It has also provided treatment for staff who have contracted COVID-19 and guaranteed the income for staff with COVID-19 related sick leave.

5. Conclusion

During an epidemic or pandemic, the execution of surgery requires different protocol levels, which apply known guidelines to local capacity and needs. The operating room must be ready to modify structures, workflow, processes, and evaluation to manage infectious patients safely. This approach requires a multidisciplinary approach such as anesthesiologists, surgeons, nurses, infection specialists, infective prevention team, pharmacy, and non-medical staff to develop meticulous but effective surgical care. The core of the surgical protocol during the COVID-19 pandemic is always and will be the safety of both our health care workers and patients.[33]

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Additional information

1 RSHS Bandung COVID-19 simulations https://www.youtube.com/watch?v=i1U7MewL3uU&t=360s
2 RSHS Bandung COVID-19 airway management https://www.youtube.com/watch?v=2t1MW4CsVnE&t=503s
3 RSHS Bandung doffing protocol for infectious disease https://www.youtube.com/watch?v=2xSzOhpNue4
4 RSHS Bandung donning protocol for infectious disease https://www.youtube.com/watch?v=cdt2hxOs0T4

CRediT author statement

Gezy Giwangkancana: conceptualization, methodology, investigation, writing the original draft. Alia Rahmi: software, data curation, original draft preparation. Indriasari: resources, data curation, writing-reviewing and editing. Nucki Nusjamsi Hidayat: writing - reviewing and editing, supervision.

Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.pcorm.2021.100198.

Reference

1 World Health Organization COVID-19 December Dashboard {online} Available from https://COVID19.who.int/?gclid=Cj0KCQiAlsv_BRDtARIsAHMGVSbKKHFVB36APU3PCMw1FLJux_gVguKIL9LwCuvItmh6R06gCFoYC6UaAooOEALw_wcB [accessed January 2021].
2 Indonesian Ministry of Health COVID-19 Positive Reports Available from http://www.padk.kemkes.go.id/article/read/2020/03/24/17/berita-positif.html [accessed December 2020].
3 Van Doremalen N, Bushmaker T, Morris DH, et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *N Engl J Med.* 2020;382(16):1564–1567. https://doi.org/10.1056/NEJMc2004973, 16th.
4 World Health Organization Clinical Management of COVID-19 Interim Guidelines May 2020. Available from https://www.who.int/publications/i/item/clinical-management-of-COVID-19 [accessed December 2020].
5 Indonesian Ministry of Health Pedoman Pencegahan dan Pengendalian Coronavirus Disease (COVID-19). 5th edition. 2020. Available from https://COVID19.go.id/p/protokol/pedoman-pencegahan-dan-pengendalian-coronavirus-disease-COVID-19-revisi-ke-5 [accessed December 2020].
6 Alizo G, Onayemi A, Sciarretta JD, Davis JM. Operating room foot traffic: a risk factor for surgical site infections. *Surg Infect (Larchmt).* 2019;20(2):146–150. https://doi.org/10.1089/sur.2018.248. Feb/MarEpub 2019 January 16th. PMID: 30648925.
7 Stauning MT, Bediako-Bowan A, Andersen LP, et al. Traffic flow and microbial air contamination in operating rooms at a major teaching hospital in Ghana. *J Hosp Infect.* 2018;99(3):263–270. https://doi.org/10.1016/j.jhin.2017.12.010. Jul.
8 Shah M, Ho J, Zhong A, et al. In a time of need: a grassroots initiative in response to PPE shortage in the COVID-19 pandemic. *Healthc Q.* 2020;23(2):9–15. Juldoi: 10.12927/hcq.2020.26282. PMID: 32762813.
9 George MP, Maier LA, Kasperbauer S, Eddy J, Mayer AS, Magin CM. How to leverage collaborations between the BME community and local hospitals to address critical personal protective equipment shortages during the COVID-19 pandemic. *Ann Biomed Eng.* 2020;48(9):2281–2284. https://doi.org/10.1007/s10439-020-02580-3. SepEpub 2020 July 24th. PMID: 32710248; PMCID: PMC7380659.
10 Gatti M, Calandra M, Barba M, Biondo A, Geninatti C, Gentile S, et al. Baseline chest X-ray in coronavirus disease 19 (COVID-19) patients: association with clinical and laboratory data. *Radiol Med.* 2020;125(12):1271–1279. DecDOI: 10.1007/s11547-020-01272-1. Epub 2020 September 7th. PMID: 32894449; PMCID: PMC7475717.
11 Tolia VM, Chan TC, Castillo EM. Preliminary results of initial testing for Coronavirus (COVID-19) in the emergency department. *West J Emerg Med.* 2020;21(3):503–506. https://doi.org/10.5811/westjem.2020.3.47348. thPMID: 32223871; PMCID: PMC7234708.
12 Kim GU, Kim MJ, Ra SH, et al. Clinical characteristics of asymptomatic and symptomatic patients with mild COVID-19. *Clin Microbiol Infect.* 2020;26(7):948.e1–948.e3. https://doi.org/10.1016/j.cmi.2020.04.040. JulEpub 2020 May 1st. PMID: 32360780; PMCID: PMC7252018.
13 American Patient Safety Foundation Recommendations for OR Ventilation during the SARS COV-2 Pandemic – Staying Positive. Available from https://www.apsf.org/article/recommendations-for-or-ventilation-during-the-sars-cov-2-pandemic-staying-positive [accessed December 2020].
14 Coccolini F, Perrone G, Chiarugi M, Di Marzo F, Ansaloni L, Scandroglio I, et al. Surgery in COVID-19 patients: operational directives. *World J Emerg Surg.* 2020;15(1):25. https://doi.org/10.1186/s13017-020-00307-2.
15 Tan Z, Phoon PHY, Zeng LA, Fu J, Lim XT, Tan TE, et al. Response and operating room preparation for the COVID-19 outbreak: a perspective from the National Heart Centre in Singapore. *J Cardiothorac Vasc Anesth.* 2020;34(9):2331–2337. https://doi.org/10.1053/j.jvca.2020.03.050. SepEpub 2020 March 29th. PMID: 32303395; PMCID: PMC7156245.
16 American Society of Anesthesiologists. https://www.asahq.org/about-asa/governance-and-committees/asa-committees/committee-on-occupational-health/coronavirus. [Accessed December 28th, 2020].
17 US Health and Human Services Center for Disease Control (CDC) https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#tableb1 [Accessed December 28th, 2020].
18 Yen MY, Chiu AW, Schwartz J, et al. From SARS in 2003 to H1N1 in 2009: lessons learned from Taiwan in preparation for the next pandemic. *J Hosp Infect.* 2014;87(4):185–193. Augdoi: 10.1016/j.jhin.2014.05.005.
19 Ragusa PS, Bitterman A, Auerbach B, Healy 3rd WA. Effectiveness of surgical safety checklists in improving patient safety. *Orthopedics.* 2016;39(2):e307–e310. https://doi.org/10.3928/01477447-20160301-02. Mar-Apr.
20 Hirota K. Air contamination with SARS-CoV-2 in the operating room. *J Anesth.* 2020:1–4. https://doi.org/10.1007/s00540-020-02814-7.
21 Collins SJ, Newhouse R, Porter J, Talsma A. Effectiveness of the surgical safety checklist in correcting errors: a literature review applying Reason's Swiss cheese model. *AORN J.* 2014;100(1):65–79. https://doi.org/10.1016/j.aorn.2013.07.024. Jule5.
22 Zhou J, Otter JA, Price JR, et al. Investigating SARS-CoV-2 surface and air contamination in an acute healthcare setting during the peak of the COVID-19 pandemic in London. *Clin Infect Dis.* 2020. https://doi.org/10.1093/cid/ciaa905. Jul 8:ciaa905.
23 Dexter F, Parra MC, Brown JR, Loftus RW. Perioperative COVID-19 defense: an evidence-based approach for optimization of infection control and operating room management. *Anesth Analg.* 2020;131(1):37–42. Jul.
24 Martínez Lamas L, Diz Dios P, Pérez Rodríguez MT, et al. Is povidone iodine mouthwash effective against SARS-CoV-2? First in vivo tests. *Oral Dis.* 2020. Jul2: 10.1111/odi.13526. doi: 10.1111/odi.13526.
25 Kim HJ, Ko JS, Kim TY. Recommendations for anesthesia in patients suspected of COVID-19 Coronavirus infection. *Korean J Anesthesiol.* 2020;73(2):89–91. Apr.
26 Herman JA, Urits I, Kaye AD, Urman RD, Viswanath O. COVID-19: anesthesia Management Recommendations. *J Clin Anesth.* 2020, 109840. https://doi.org/10.1016/j.jclinane.2020.109840.
27 Fransvea P, Sganga G, Cozza V, et al. Set up of a dedicated COVID-19 surgical pathway and operating room for surgical emergencies. *J Trauma Acute Care Surg.* 2020;89(4):e97–e100. https://doi.org/10.1097/TA.0000000000002852.
28 Bao C, Liu X, Zhang H, Li Y, Liu J. Coronavirus Disease 2019 (COVID-19) CT Findings: a Systematic Review and Meta-analysis. *J Am Coll Radiol.* 2020;17(6):

701–709. https://doi.org/10.1016/j.jacr.2020.03.006. JunEpub 2020 March 25th. PMID: 32283052; PMCID: PMC7151282.
29 Gao Y, Xi H, Chen L. Emergency surgery in suspected COVID-19 patients with acute abdomen: case series and perspectives. *Ann Surg*. 2020;272(1):e38–e39. https://doi.org/10.1097/SLA.0000000000003961. JulPMID: 32301807; PMCID: PMC7188052.
30 Maynard SL, Kao R, Craig DG. Impact of personal protective equipment on clinical output and perceived exertion. *J R Army Med Corps*. 2016;162(3):180–183. Jun.
31 Luze H, Nischwitz SP, Kotzbeck P, et al. Personal protective equipment in the COVID-19 pandemic and the use of cooling-wear as alleviator of thermal stress : a pilot study in plastic surgery staff members. *Wien Klin Wochenschr*. 2020:1–9.
32 Rakotosamimanana N, Randrianirina F, Randremanana R, et al. GeneXpert for the diagnosis of COVID-19 in LMICs. *Lancet Glob Health*. 2020;8(12):e1457–e1458. https://doi.org/10.1016/S2214-109X(20)30428-9. DecEpub 2020 October 19th. PMID: 33091372; PMCID: PMC7572106.
33 Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo CG, Ma W, et al. Coronavirus pandemic epidemiology consortium. risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Public Health*. 2020;5(9):e475–e483. https://doi.org/10.1016/S2468-2667(20)30164-X. Sep.