

Recommendations to Safeguard Reconstructive Microsurgeons Performing High-risk Operations during the COVID-19 Pandemic

Nidal F. AL Deek, MD
Fu-Chan Wei, MD, FACS

Summary: An unprecedented number of health care providers have been infected and many have died during the COVID-19 pandemic. Reconstructive microsurgeons from different surgical backgrounds often are involved in the care of known COVID-19 and high-risk patients. The need for a magnification loupe/microscope makes it difficult for them to wear recommended personal protection equipment, increasing the risk of exposure. Although advanced technologies are available, they have not been exploited effectively. To date, no safety guidelines are available for safe reconstructive microsurgical procedures in high-risk operations/known COVID-19 patients—particularly, to address operations risk and COVID-19 status of the patients, who would operate, how many should be involved, how to equip the surgeons for the procedure, when to operate as the procedure unfolds, how to adapt surgical techniques to reduce exposure risk, and can advanced technology be used to minimize exposure. A set of safety recommendations were thus developed based on literature review and firsthand knowledge of safety procedures during the COVID-19 pandemic. Current understanding of COVID-19 virology can optimize surgical team buildup and dynamics. Operating smaller teams (in a sequential style), minimizing the use of aerosols-generating devices, and modifying surgical plan and flap selection could aid in diminishing the risk of exposure and in conserving resources. Modifications in loupes design, and the combined wear of surgical mask and N95 respirators, and efficient use of “buddy system” could aid in protecting surgeons during donning and doffing. “Remote operating” is a novel concept of using a surgical robot to maximize surgeons’ safety during COVID-19 pandemic. (*Plast Reconstr Surg Glob Open* 2020;8:e3215; doi: [10.1097/GOX.0000000000003215](https://doi.org/10.1097/GOX.0000000000003215); Published online 29 September 2020.)

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has caused a large global outbreak, mounting tremendous pressure on medical communities. Based on the data released by the Centers for Disease Control and Prevention (CDC) during February 12–April 9, 2020, of all those infected during the time period, only 49,370 provided data on whether the patient was health care personnel, and 19% (9282) were identified as frontline health care providers (HCP); 5% of them required intensive care, and 27 died.¹ In addition, the psychological burden is yet to be reckoned with.²

From the Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Taipei, Taiwan.

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Protection of health care practitioners and highly specialized medical teams is thus of paramount importance and should be at the center of any surgical guidelines during COVID-19 pandemic.^{1,3} Although no specific data are yet available on COVID-19 exposure and infection rates per surgical specialty, surgeries on aerodigestive tract (including otolaryngology head and neck surgery, major facial trauma surgery, chest surgery, upper gastrointestinal, cleft surgery, and some transplant procedures) are associated with an increased risk of COVID-19 transmission to the healthcare team.⁴⁻⁸ In response, a few specialty-specific guidelines have been developed,⁵ but they are hardly applicable to other surgeons involved in the multidisciplinary care of known COVID-19 oncologic, major trauma, or transplant patients—particularly, the microsurgical team performing lengthy high-risk free tissue transfer procedures for defects in those patients.

Such protocols are urgently needed. A reconstructive microsurgeon often starts to harvest different body tissues/

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flaps, while other teams proceed with their work at the same time—for instance, with tracheostomy, open chest surgery, or laryngeal and oropharyngeal tumor extirpation, which lasts for hours after the resection is done, subjecting the team to a potential hazard due to an increase in duration or frequency of exposure.⁸ Microsurgery also requires specific setup and equipment like a magnification loupes and operating microscope, which make it difficult for surgeons to wear recommended personal protection equipment. On the other hand, advanced technology is available, which is yet to be utilized to maximize safety and could be worthy of considerations and implementation in any guidelines.

In this work, safety recommendations have been developed to protect the reconstructive microsurgeons who come from general surgery, otolaryngology head and neck, maxillofacial, plastic, and neurosurgery backgrounds. They are limited in number even in major medical centers, and hardly renewable due to the special rigorous and lengthy training required, but usually in charge of performing major reconstructions in high-risk operations or known COVID-19 patients. Nevertheless, per American College of Surgeons, the following factors need to be considered: Patient's medical needs versus logistical capability, in real time, and the medical need for a given procedure and aggregate assessment of the real risk of proceeding versus real medical risks incurred by case delay.⁹

PREPARATION OF GUIDELINES

The proposed guidelines have been based on the information available on virus epidemiology, CDC reports, existing guidance from infection control specialty to surgeons at risk, guidelines suggested by specialties that combine care with reconstructive microsurgeons, systematic reviews and metaanalysis when available, as well as authors' genuine creative thoughts.

The guidelines serve to answer the following: What is the extent of operations risk? and what is the COVID-19 status of the patients? Who would operate? How many should be involved? How to equip for the procedure? When to operate as the procedure unfolds? How to adapt surgical techniques to reduce exposure risk? Can advanced technology be used to minimize exposure?

THE EXTENT OF OPERATIONS RISK AND COVID-19 STATUS OF THE PATIENTS

Choosing to operate is a major decision and should be discussed among the multidisciplinary team, adhering to American College of Surgeons recommendations, with the aim to postpone the surgery as deemed suitable based on the American College of Surgeons guidelines.⁹ The next thing worth considering is to determine the risk of the procedure. Operations can be classified into high-risk and low-risk operations, and patients at the time of surgery are considered COVID-19-positive until proved otherwise by repeated testing while in hospital. Any aerosol-generating procedure (AGP), and all procedures on patients with known COVID-19, unknown status (under testing), flu-like symptoms, or fever should be considered high risk. Only a non-AGP on COVID-19-negative patients

after repeated testing 48 hours before surgery can be considered a low-risk surgery.⁵

WHO PERFORMS THE SURGERY?

Surgeons are no exception from the population affected by the global pandemic. Understanding COVID-19 virology, epidemiology, and disease characteristics in various patient populations can help identify and protect vulnerable surgeons, and optimize the selection of team members.

Who Could Be at a Higher Rate of Infection?

As shown in previous studies, angiotensin-converting enzyme 2 (ACE2) is the SARS-CoV-2 receptor, and the receptor-binding ability of SARS-CoV-2 is 10–20 times stronger than that of SARS-CoV.^{10–12} Men have a higher ACE2 level in their alveolar cells than do women. Asians have a higher level of ACE2 expression in their alveolar cells than do the White and African American populations.¹²

Who Could Be at Risk of Rapid Progression or Severe Complications?

Wang et al¹³ found that the median time from early symptoms to death in people aged 70 years or older (11.5 days) was shorter than that in people aged under 70 years (20 days). Huang et al¹⁴ found that 32% of the patients had underlying diseases, including diabetes, hypertension, and cardiovascular disease, with a median age of 49 years and 15% fatality rate. Therefore, fast progression can be anticipated in patients aged 70 years or older, but younger patients with preexisting conditions are also vulnerable, with a high fatality rate.¹⁵ Similarly, the CDC report on characteristics of HCP with COVID-19—United States, February 12–April 9 showed that 38% of HCP had at least one underlying medical condition, and death occurred across all age groups, but most frequently in HCP aged ≥65 years (37%).¹

The other group at risk is patients on ACE inhibitors or those with underlying lung conditions with a high expression of ACE2. The binding of SARS-CoV-2 on ACE2 receptors causes an elevated expression of ACE2, which can lead to damages on alveolar cells, which, in turn, can trigger a series of systemic reactions and even death.¹⁵

Based on these pieces of evidence, when it comes to the selection of the reconstructive microsurgeon as to who will operate on a COVID-19 patient, when possible, especially in countries with racial mix, one can call upon the experienced capable younger surgeons aged ≤ 50 years; female surgeons; non-Asian male surgeons; surgeons without chronic lung disease (inclusive of asthma, chronic obstructive pulmonary disease, and emphysema); diabetes mellitus; cardiovascular disease; chronic renal disease; chronic liver disease; immunocompromised condition; pregnancy; current/former smoking status; or other chronic disease. Elderly, retired, and surgeons with underlying medical conditions should not be called upon to operate on confirmed and high-risk cases, not mentioning they should not be sent to the frontline to begin with.

HOW MANY SURGEONS PER CASE?

To avoid exhausting the limited number of reconstructive surgeons over a short period of time and to accommodate for emergencies related to microsurgical reconstruction, we recommend a maximum 2-personnel approach composed of 1 attending surgeon and 1 assistant, who all should meet the criteria proposed earlier. Because of the mental and psychological burden associated with operating on COVID-19 patients,² we recommend that team assembly considers pre-existing bonds and familiarity among team surgeons. In case of emergency/take back of the patient, we recommend that the same team handles the crisis to avoid implicating new team members and potentially losing more capable individuals for disease and/or quarantine.

Depending on staffing levels and workforce resources, we suggest splitting the reconstructive microsurgery force into a few smaller teams to cover a 14-day period, each compatible with CDC guidelines.¹⁶ After each cycle, a new team take over while the previous team rest, put under quarantine, and receive adequate testing/treatment.

HOW TO EQUIP FOR THE PROCEDURES?

SARS-CoV-2 has recently been categorized based on the risk to humans as a hazard group 3 organism,¹⁷ but it may soon be considered a hazard group 4 organism. The virus has been detected in bronchoalveolar fluid, sputum, feces, blood, and urine, besides respiratory droplets.¹⁸ In a dedicated SARS-CoV-2 outbreak center in Singapore, physicians' shoe covers and surfaces have tested positive, though culture was not done to demonstrate viability.¹⁹ In experimental settings, the virus can remain viable and infectious in aerosols for 3 hours and on surfaces up to several days (depending on the inoculum shed).²⁰ Similarly to hepatitis B virus detected in surgical smoke from the use of electrocautery,²¹ it will not be a surprise to isolate SARS-CoV-2 in surgical smoke. Therefore, it is wise to consider the entire operating room (OR) contaminated and to protect the surgical team in the most effective manner.

Personal protective equipment should include:

- Surgical scrubs.
- Single-use disposable scrub hat.
- Waterproof surgical gown to cover whole body and forearms.
- Plastic apron.
- Rubber boots.
- Protective Kevlar or cut-resistant under-gloves fabrics.
- Double, single-use disposable non-latex gloves.
- Mask, respirators, and eye and face protection require further discussion; see below.

For a low-risk operation, surgeons can choose not to wear a plastic apron, rubber boots, and protective Kevlar. Eye and face protection should remain unchanged.

Masks and Respirators

N95, powered air purifying respirators, and surgical masks are the currently available masks and respirators to fend off SARS-CoV-2. None of them is ideal.

N95, though capable of filtering aerosols, did insignificantly reduce the incidence of laboratory-confirmed

influenza compared with a surgical mask that has no filtering capabilities.²² However, N95 fits more tightly than a surgical mask.

Powered air purifying respirators reduce the risk of exposure even more than N95 and are better fitted. However, they could compromise the sterile surgical field, as they do not filter the discharged air. They are cumbersome and limit visibility when they fog up and make using headlight or magnification loupes especially difficult. Suitability when using a microscope is unclear. Donning and doffing could risk self-exposure.^{5,23–25}

The CDC in the United States specifically recommends the use of N95 respirators (preferably without valves) for surgeries with AGPs on COVID-19 patients.²⁶ Based on the available information and recommendations, we suggest using a well-fitted N95 and a standard surgical mask on top of it; particularly, during any phase in which patient's blood or fluid can gush out, as in the free flap harvest phase. The surgical mask acts as cheap, replaceable protection layer against blood/fluid burst and contamination; it can easily be removed and replaced without exposure risk, prolonging probably the lifetime of N95.

Eye Protection

Infection with SARS-CoV-2 through the eyes has been reported.²⁷ Eye protection is essential but complicated for the reconstructive microsurgeon due to wearing magnification loupes. The following can be recommended:

- 1- Through-the-lens loupes equipped with flipped flat panel (Designs for Visions, Inc.) or with a face shield that is modified to allow long-design loupes to pass through holes in the face shield. The disadvantage of this eye protection may lead to a potential exposure risk when removing the shield and loupes to operate under the microscope. It is also uncomfortable. A solution here is to split the team of single operator into 2, one wears the previous eye protection and performs flap harvest. The other wears only tightly fitted goggles and is responsible for inset and microanastomosis.
- 2- *Through-the-lens loupes and visors/silicon eye cap* (Designs for Vision, Inc). This is a more comfortable option. However, it bears the same risk as above. The same solution described above can be utilized. Some surgeons may prefer to rely on loupes totally and do not require a microscope. For them, the above 2 forms of protection could be adequate; however, the standard, widespread practice remains the one under microscope, and therefore above recommendations are warranted.
- 3- *Flip-up loupes and visor/silicon eye cap with/without face shield*. This is the most practical and comfortable option. The flip-up loupes can be removed while the glasses and visors/silicon eye cap stay. The loupes can also be mounted on tightly fitted goggles. This option does not require splitting the team into 2; 1 with loupes and 1 without.

Donning and doffing are opportunities for risk exposure.²⁸ To minimize such a risk, a "buddy system," based on previous viral outbreaks, has been recommended, in which providers assist with and oversee the doffing of

a colleague.²⁹ Alternatively, video-assisted instructions demonstrating donning and doffing, adopting a similar approach when performing routine safety check and evacuation procedures when boarding airplanes before take off, could be put to work. We cannot emphasize enough that protocols, rehearsals, and modifications of personal gears need to be set as soon as possible and in advance to ensure safety of surgical teams and flawless performance.

WHEN TO OPERATE AS THE PROCEDURE UNFOLDS?

Although currently most reconstructive microsurgeons often start harvesting workhorse flaps from the lower extremity when other teams begin their ablative surgery on aerodigestive tract, it is not advised in the setting of high-risk operation or known COVID-19 patients. To minimize the risk of exposure and crowding the OR, we would like to suggest a sequential approach instead of a simultaneous one. The reconstruction team enters the OR only after the ablation team have completed their resection, sources of potential infection spread are sealed by Tegaderm, a minimum of 20-minute break has been undertaken based on the number of air changes per hour, as described by the CDC,¹² and the theatre has been adequately disinfected.

Adapt Surgical Plan and Techniques to Reduce Exposure Risks and Perioperative Complications

The adaptation to high-risk operations or operations on known COVID-19 patients should aim at: (1) shortening operation time to decrease the length of exposure and minimize perioperative complications, (2) minimizing blood loss due to potential shortage of blood availability related to shelter-in-place requirements that reduce public access to blood donation facilities, (3) reducing AGPs, including the use of powered devices (eg, drills, microdebriders, saws) or ultrasonic shears, such as the Harmonic scalpel (Ethicon) or Thunderbeat scalpel (Olympus) because transmission through aerosolization of blood via the use of energy devices used for hemostasis and in dissection has been documented, (4) effective elimination of smoke and aerosols through the use of a smoke evacuation device, and (5) decreasing intensive care unit stay and the length of hospitalization in an attempt to preserve resources and also to reduce in-hospital transmission.^{5,8,30,31}

That being said, we recommend (1) realistically assessing the medical need for a procedure and the real risk of proceeding versus another procedure or even a delay, (2) carefully considering less time-consuming non-flap options such as local tissue rearrangement, VAC, etc when applicable, (3) simplifying the reconstruction by aiming at achieving rapid and uncomplicated healing in shorter surgery and hospital stay, such as pedicle flap over free flaps for extremity/trunk reconstruction, and single free flap over double free flaps in 2-stage reconstruction with soft tissue flap first when bone defect is compound or composite one, (4) using workhorse flaps you have mastered, (5) using free flaps that do not require

position change, (6) selecting free flaps that require no intramuscular dissection, such as the radial forearm flap and composite flaps.

Can Advanced Technology Be Used to Minimize Exposure?

The short answer is yes—by utilizing remote operation. In this section, we have envisaged unprecedented application of the robot-assisted reconstructive surgery in high-risk operations or operations on known COVID-19 patients.

When robotic unit is available, robot-assisted procedures allow the surgeon to operate farther from the source of potential infection such as the aerodigestive tract, avoiding direct exposure. This is advantageous and applicable during intraoral flap inset,³² vessels repair, including liver transplantation, or away from other surgical teams during flap harvest of the latissimus dorsi muscle flap, and the deep inferior epigastric artery perforator flap,^{33,34} allowing the simultaneous approach with less OR crowding.

Furthermore, and while this is not described before, the robot counsel unit can be stationed in an adjacent room instead of the same room where the procedure is carried out, for ultimate protection of the operating surgeon. When this is attempted, OR air pressure flow needs to be considered. If the OR where the surgery is performed is a positive air pressure flow room, personal protection equipment effective against aerosolized particles will be needed in the room where the counsel is stationed. But when the OR is a negative air pressure flow room, recommended for COVID-19 patients,³⁵ a surgical mask could suffice.

Effective utilization of remote operation can aid the effort in minimizing the number of operators involved, as robots have multiple arms that can multitask. With rehearsal, it could be possible to harvest the flap, inset, and repair vessels remotely with trained assistant intervening for proper arming and positioning while the experienced surgeon remains sheltered from the risk, or has a shorter exposure time.

CONCLUSIONS

Reconstructive microsurgeons are essential to the care of known COVID-19 patients receiving major reconstruction after tumor ablation, facial trauma, chest surgery, and transplant procedures, and are at a high risk of infection due to the high-risk nature of those surgeries, their long duration, and their aerosols generating tendencies. This article was prepared as in-advance pandemic response plan for reconstructive surgical services.

In this work, we utilize current understanding of COVID-19 virology to optimize surgical team buildup and dynamics, which allows authorities to guide surgeons' selection so that less is infected, and even when infected, they are less likely to endure serious complications. We recommended operating smaller teams, operating in a sequential style for less crowding, minimizing the use of aerosol-generating devices and modifying surgical plan and flap selection to diminish the risk of exposure and to conserve resources. This article novelistically advocates the concept of "remote operating" with a surgical robot to maximize safety and to decrease the exposure of surgeons during COVID-19 pandemic. We also

recommend the combined wear of surgical mask and N95 respirators and addressed eye protection in a way suitable to reconstructive surgeons. All patients considered were either COVID-19-positive or unknown (but under test) unless proved otherwise by repeated testing within 48 hours from surgery. Finally, American College of Surgeons' guidelines should be followed, and refinements or amendments should be considered as the situation unfolds, and more experts share their feedback or experiences.

Fu-Chan Wei, MD, FACS

Department of Plastic and Reconstructive Surgery
Chang Gung University Medical College
Chang Gung Memorial Hospital
199 Tun-Hwa North Road
Taipei 10591, Taiwan
E-mail: fuchanwei@gmail.com

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