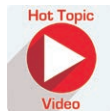


A Multidisciplinary Approach and Review of Safety Recommendations for Plastic Surgeons during the COVID-19 Pandemic: Are N95 Masks Enough?

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Summary: The novel coronavirus disease of 2019 pandemic presents a unique challenge to the field of plastic and reconstructive surgery. Although plastic surgeons may be postponing elective operations, there are still a number of emergent or urgent procedures that may need to be performed, and surgeons may be facing the reality of returning to a new normalcy of operating with coronavirus disease of 2019. These procedures, consisting of those such as head and neck reconstruction or maxillofacial trauma, largely require a multidisciplinary approach and may be considered of higher risk to health care workers because of the involvement of areas of the body identified as sources for viral transmission. Moreover, viral transmission may potentially extend beyond respiratory secretions, which has been the main focus of most safety precautions. The authors aim to present the scope of these procedures and the means of viral transmission, and to provide safety precaution recommendations for plastic surgery and its related disciplines. (*Plast. Reconstr. Surg.* 148: 467, 2021.)

The novel coronavirus disease of 2019 (COVID-19) pandemic presents a unique challenge to the field of plastic and reconstructive surgery, a discipline that also interfaces with otolaryngology–head and neck surgery, Mohs micrographic surgery, and oral and maxillofacial surgery. Several societies have provided their guidelines about safety.^{1–4} Although evolving recommendations provide an overview of specialty-specific guidelines, they are not geared toward plastic surgeons in urgent or emergent cases, or when returning to a new normalcy of operating despite the COVID-19 pandemic.

The specific transmission rate to health care workers is not yet known; however, health care workers likely have at least a three-fold increase in the risk of infection compared to the general public based on data from China and Italy.⁵ Even in the event of providers testing positive for antibodies, there is not enough information at the present time to know the duration of these antibodies

or the extent of protection from future infections. As such, the providers should still take appropriate safety precautions regardless of COVID-19 antibody status. As surgeons, we have a dual responsibility to provide appropriate treatment to our patients while taking care to prevent transmission.² Safety is paramount to continue providing appropriate care to patients with and without COVID-19. Aside from conventional routes of viral transmission through airborne droplets, we review other potential forms of transmission in the form of aerosolized viral titers created by electrocautery.

OUTPATIENT EVALUATION

Use of proper personal protective equipment is paramount. When examining patients, examiners need to understand that certain regions, such as the head and neck, are high risk because of coronavirus transmission by droplets and the

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high potential for aerosolization because of the high concentration of viral load in the nasopharynx. To et al. noted a viral load of $5.2 \log_{10}$ copies per milliliter found in the respiratory specimens from 23 of their infected patients.⁶ Although the infectious viral load has not yet been identified, there are a few facts that have been reported. We know that the virus can be spread through human transmission and potentially lingers in the air for up to 3 hours, and on various surfaces from 24 hours to 3 days.⁷ Studies have shown that the virus concentration peaks following initial presentation of symptoms and declines over the course of 1 week, with the virus being easily transmissible from asymptomatic or mildly symptomatic people.^{6,8} Another study revealed that concentration levels of viral RNA may be associated with the severity of symptoms.⁹

The Centers for Disease Control and Prevention has already recommended contact and airborne protections with personal protective equipment and N95 masks.^{5,10} Use of N95 masks, which can filter particles $0.3 \mu\text{m}$ or smaller, are especially crucial, given that surgical masks do not provide the recommended minimum level of protection by the Occupational Safety and Health Administration. Although surgical masks can certainly protect providers from large droplets, they are not as reliable for smaller particles, given that they do not adhere to the same standards as N95 masks. Moreover, the primary design of surgical masks is to protect the other party from the wearer; in this case, the patient from the provider. There are also standards of fit and seal that do not apply to surgical masks and therefore decrease the effectiveness of protection from airborne disease. According to the data, protectiveness against particles for surgical masks is eight to 12 times less than that for N95 masks.¹¹ One other consideration is the difference between the duckbill and the more standard dome-shaped N95 masks, with the former sometimes being considered more comfortable. It was found that 70.6 percent of reused duckbill N95 masks versus 27.5 percent of reused dome-shaped N95 masks failed fit testing.¹² The impact of appropriate ventilation is also important when used for COVID-19–suspected or –positive patients, with the Centers for Disease Control and Prevention suggesting negative-pressure rooms for any continuous aerosol procedures being performed and closed private doors otherwise.¹³

One other mechanism that may often be overlooked is ocular transmission, making eye protection in the form of goggles or face shields

imperative. Viruses such as influenza or severe acute respiratory syndrome–coronavirus, and human papilloma virus or respiratory syncytial virus, have all been reported to be transmissible through contact with the mucous membranes of unprotected eyes.^{14–17} Not only that, there have been reports of COVID-19 potentially transmitting by means of the ocular route, supported by symptoms of conjunctivitis and the virus being found in ocular secretions, and anecdotal cases of individuals infected following exposure to COVID-19 patients despite wearing personal protective equipment apart from eye protection.^{18–20}

Precautions need to be taken for any asymptomatic patient, which would include at a minimum gloves, mask, eye protection for the examiner, and mask for the patient. For any patient who is suspected of having or is positive for COVID-19, ideally, the examination should be deferred until the patient has recovered. Alternative means of evaluation by means of telehealth (video conference) should be considered. If such a patient needs to be evaluated in an urgent manner, full personal protective equipment is needed, including N95 masks, gown, gloves, hat, eye protection for the examiner, and surgical mask for patient. The examination should be performed by the most experienced provider.

EMERGENCY ROOM EVALUATION

A triage telephone line should be established for daily dental or oral surgery emergencies with the ability for remote telemedicine visit by the health care provider for a higher level of consultation, eliminating in-person visits unless deemed urgent or emergent.^{4,5} Urgent care examples include acute dental abscess, acute facial or neck swelling, trismus or difficulty opening the mouth, pain while swallowing, bleeding from the oral cavity, or acute oral mucosa swelling because of allergic reaction and maxillofacial injuries.^{21–23} Mucosal lesions/injuries can have high aerosolizing potential, and any in-person visits require full personal protective equipment, including N95 mask, face shield, gown, and gloves. The patient should be evaluated by the most experienced provider to minimize exposure time to the provider. A negative-pressure room should be used for procedures such as dental extractions or transoral incision and drainage of an abscess, or dentoalveolar fractures.

Many providers in plastic surgery are involved with the management of facial trauma. Patients with mucosal injuries have a higher risk of

aerosolization of their mucus and pose a transmission threat to the provider.^{1,5} As with any high-risk evaluation, the provider must examine such patients with full personal protective equipment, including N95 masks, eye protection, gown, and gloves, because of the high risk of aerosolization. Patients with extensive injuries should have their airway secured early with the assistance of anesthesia to minimize aerosolization for all providers.

Burn injuries often present with concurrent traumatic injuries, including those to the neck and airway. The assessment of a patient with burn injuries should always begin with the standard trauma survey. Those with major burns, especially airway injuries, are at high risk of requiring airway support. The provider must examine such patients with full personal protective equipment, including N95 masks, eye protection, gown, and gloves, because of the high risk of aerosolization. Patients with extensive burns or airway injuries should be intubated early, ideally with the assistance of anesthesia or another experienced provider, to minimize viral transmission risk. Burns involving a large total body surface area (over 50 percent) can be associated with hemodynamic instability, fluid overload, pulmonary injury, sepsis, and acute compromise of the immune system, all of which can complicate their critical care management. The presence of an acute COVID-19 infection in a burn-injured patient would likely further complicate the course, putting them at high-risk of a poor pulmonary outcome. It is of utmost importance to reduce the risk of viral transmission to burn-injured patients without acute infection from COVID-19, and to anticipate the challenging clinical course of a patient with these concurrent diagnoses. It is advisable to proceed early with a lung protective ventilation strategy and judicious fluid management to maximize oxygenation and minimize fluid creep.

PREOPERATIVE EVALUATION

If possible, determine the severe acute respiratory syndrome–coronavirus 2 infection status of the patient beforehand. Each institution has its own protocol that can be adhered to. If a patient is positive, a careful assessment of risk to patient and the health care providers should be performed by a multidisciplinary team before the operation is recommended. Operating on mucosal surfaces in a patient who is actively infected generates a significant risk for the entire operating room and recovery units. It may also compromise the patient's ability to recover from the infection.¹

The current literature also certainly does bring to light the fact that patients with COVID-19 may have a hypercoagulable state, as found in various abnormalities ranging from increased fibrinogen, D-dimer, and factor VIII, to direct endothelial injury. As may be expected because of the more commonly known effects of COVID-19 on the lungs as a target organ, pulmonary microvascular coagulation has been a noted finding. However, more systemic features have been suggested, supported by reports of increased prevalence of venous thromboembolism in the patient population, even despite the use of prophylaxis.^{24–26} Given that those who receive microsurgical procedures in particular may be at risk for not only venous thromboembolism but also thrombotic events of the anastomosis and flap itself, the use of venous thromboembolism prophylaxis is especially important when operating on COVID-19–suspected or –confirmed patients. Although there are not yet clear guidelines for venous thromboembolism prophylaxis for the COVID-19 patient, current trials are being conducted to investigate whether higher than conventional doses may be beneficial.

OPERATING ROOM

Personal Protection

If possible, negative-pressure rooms are recommended. All personnel in the operating room need to have a planning huddle. Intubation should be performed by anesthesia personnel with appropriate personal protective equipment; surgeons can be outside the room. Full personal protective equipment should be donned, including N95 masks, gowns, gloves, and eye shields.^{9,10} Personal protective equipment should be kept on until the patient is out of the operating room and no further immediate contact is planned, as aerosol may land on clothing or even unprotected mucous membranes, such as when extubation is performed.

Aerosol

Certain procedures may generate aerosol and therefore expose medical professionals to the risk of infection. Eight families of virus, including Coronaviridae, have been in particular noted as high risk based on being infectious by means of aerosol, evidence that they are found in the respiratory tract, and previous reports of nosocomial transmission.²⁷ Although it is unknown whether COVID 19 is transmissible through plasma or

serum and there is no current evidence supporting transmission in this regard, the literature has also reported that viral RNA can be detected in the bodily fluids of infected patients. This is especially of note given that there have been previous reports on the aerosolization of infected fluids, such as blood.^{28,29}

Moreover, smoke or plume generated from Bovie use or lasers may also carry with it this potentially infectious aerosol.³⁰ There do not appear to be current studies on the viral load found within generated aerosols from COVID-19 patients; however, there has been an example of detectable viral load in surgical smoke for hepatitis B, *Corynebacterium*, human papillomavirus, poliovirus, and human immunodeficiency virus.^{31–36} In particular, as reported in the literature, surgical smoke has been linked to transmission of human papillomavirus,³⁷ which has a diameter of approximately 50 to 60 nm and is most commonly transmitted sexually, compared to a diameter of approximately 60 to 140 nm for COVID-19, which is most commonly transmitted by means of respiratory droplets.^{38,39} In addition, there is evidence to suggest the potential for deposition of particulate matter on the respiratory tracts of surgical staff from surgical smoke, as illustrated by a study demonstrating the substantial mass concentration and size distribution of smoke particles following electrocautery of porcine tissue.⁴⁰ Table 1 notes various potential routes of viral transmission in different procedures and Table 2 notes the risk of different exposures and recommended safety precautions.

Surgical smoke particles typically range from 0.01 to 1 µm, with 77 percent being smaller than

1.1 µm. Particles smaller than 10 µm are inhalable, and those smaller than 2.5 µm precipitate in the alveolar region of lungs and those smaller than 0.1 µm deeply penetrate the respiratory system.^{41,42} The Centers for Disease Control and Prevention has recommended the use of mechanical local exhaust ventilation smoke evacuation systems with high-efficiency filtration systems when performing procedures on human papillomavirus-infected tissues,⁴³ and this may be applicable when operating on COVID-19 patients, especially taking into account our current lack of understanding regarding its transmissibility in this regard. It has also been recommended to have filtered central wall suction units, install local exhaust ventilation suction apparatuses no more than 2 inches away from the source with a capture velocity of 100 to 150 feet/minute, and avoid electrocautery when possible.^{44–46}

Care of the Tracheostomy

Tracheostomy care needs to be approached with caution, including placement of tracheotomy during the case because of high aerosolization, and it has been previously reported during the severe acute respiratory syndrome–coronavirus outbreak that health care workers performed or being exposed to tracheal intubation procedures had a higher risk of transmission.²⁹ This requires communication with anesthesia to create apnea when the tracheostomy tube is inserted in the patient. Cuffed, nonfenestrated tubes should be used and the cuff inflated, and the patient should be attached to the ventilation circuit. Postoperative management also requires all personnel involved to wear full personal protective equipment, including N95 respirators, gowns, gloves, and masks.

Microvascular Surgery

The goal should be to reduce the time spent in the operating room; thus, the most experienced surgeons should be performing the operation. Exposure of trainees especially in a COVID-19–positive patient needs to be minimized. Potential avoidance of electrocautery, as noted earlier, is one strategy to eliminate viral loads in a Bovie plume.

PROCEDURES

Plastic surgeons perform a broad range of procedures from head to toe and in different settings, whether electively or following trauma or oncologic resection. This may make it particularly difficult to determine which operations should be performed

Table 1. Potential Routes of Transmission for Different Procedures

Mode of Transmission	Operations with Risk of Transmission
Ocular secretions	1. Maxillofacial trauma 2. Periorbital lesion
Respiratory secretions	1. Maxillofacial trauma 2. Head and neck reconstruction 3. Head and neck abscess 4. Tracheostomy 5. Perioral and nasal lesions 6. Surgery on symptomatic patient (coughing)
Surgery particulate-generated aerosol	1. Maxillofacial trauma 2. Periorbital lesion 3. Head and neck reconstruction 4. Head and neck abscess 5. Abdominoperineal reconstruction 6. Large-surface-area operations on patients with high viral load or viral load noted in blood

Table 2. Recommended Safety Precautions for Different Exposures

Exposure Event	Exposure Time (min)	Risk Level*
Consultation in room for <15 min; distance, 3–6 ft	15	Very low
Visual examination of oral cavity	5–10	Very low, low
Closure of oral lacerations and intraoral mucosal biopsy	30–60	Low, medium
Dental extraction (single or multiple), without drill	15–60	Medium
Closed reduction of mandibular fractures	45–60	Medium
Incision and drainage of deep neck fascial space, odontogenic infection, transcervical and transoral	30–90	Medium, high
Closed reduction of midface fractures including nasal bones, without drill	45–90	Medium, high
Removal of malignant tumors with or without neck dissection	60–80	High
Open reduction and internal fixation of facial fractures, with drill	120–320	High, very high
Extraction of multiple teeth, with drill	60–120	High, very high
Resection of malignant bone tumors, with drill	>240	Very high
Tracheostomy	15–45	Very high

*Very low, recommended gloves, mask, eye protection (gown if available); Low, recommended gloves, mask, eye protection (gown if available); Medium, recommended gloves, mask, face shield, gown; High, recommended gloves, N95 mask, disposable impervious gown, full face shield with or without ventilated orthopedic hood; and Very high, recommended gloves, N95 mask, disposable impervious gown, ventilated orthopedic hood, powered air-purifying respirator, and local exhaust ventilator.

during the pandemic. [Table 3](#) outlines a framework of essential versus nonessential procedures.

Head and Neck

All head and neck reconstruction, dental or oral procedures, and maxillofacial trauma need to be approached with a high level of understanding about aerosolization and the proximity of viral loads in the mucosal surfaces of the head and neck region. Because of the viral concentration in the head and neck mucosal regions, these patients need to be deemed high risk even if COVID-19 testing is negative because of false-negative results. For nonfacial lesions, there is little aerosolization risk based on the current data, and surgery may proceed with the surgeon and assistants using standard personal protective equipment protection: gown, gloves, surgical mask, and eye protection.

Any surgery around the mouth or lips may have a higher risk of infection. Instillation of local anesthesia in the tip of the nose or the ala can induce sneezing or tearing. Positioning the patient appropriately may require special care because some patients may cough if they are not sitting upright. For such cases, ideally, surgery should be postponed. If the operation has to proceed, full personal protective equipment is needed: N95 mask, gloves, gown, and eye protection. Consideration should be given if the surgery can be postponed without increasing the risk of cancer growth, bleeding, and unresectability while balancing the risk of transmission to the health care providers. The risk of transmission of disease to patients in the health care setting also needs to be weighed. The most difficult dilemma occurs in the management of growing tumors in elderly or immunocompromised patients who also have the

Table 3. Essential versus Nonessential Procedures during the COVID-19 Pandemic

Indicated Management in COVID-19 Breakout	Procedures
Do not postpone surgery	<ol style="list-style-type: none"> 1. Trauma defects with significant exposure (bone, tendon, cartilage nerve, hardware) 2. Oncologic defects with significant exposure (bone, tendon, cartilage nerve, hardware) 3. Head and neck reconstruction 4. Alloplastic or delayed breast reconstruction 5. Orbital fracture with entrapment 6. Burns 7. Life- or limb-threatening infection 8. Compartment syndrome 9. Extremity fracture, tendon or nerve injury 10. Pediatric surgery where delay would affect growth and development 11. Acute postoperative complications
Postpone surgery	<ol style="list-style-type: none"> 1. Cosmetic operations 2. Elective operations 3. Revisions 4. Autologous breast reconstruction; consider performing delayed breast reconstruction 5. Traumatic or oncologic reconstruction without significant exposure of structures; consider placement of wound vacuum-assisted closure

highest risk both of complications from the procedure and also of mortality from COVID-19. For maxillofacial trauma, consider closed reduction of fractures, whenever feasible. If open reduction and fixation is necessary, consider using self-drilling screws.

Mohs micrographic surgery is a staged procedure performed under local anesthesia in which the tumor and some margin of normal appearing skin is removed and margins are assessed by frozen sections prepared by processing the tissue horizontally. Repeated sections are done until the tumor is cleared, after which reconstruction is performed. The patient is often in the office for several hours to almost a full day and may be moved from procedure room to waiting room and back to procedure room multiple times. Surgeons generally run multiple cases concurrently. During the coronavirus epidemic, the surgeon should reduce the number of cases so that the patient can stay in the procedure room from the beginning of the operation until discharge to home to minimize contact with large numbers of people. The room then needs to be cleaned fastidiously before the next patient, including airing the room out with high-efficiency particulate air filters for at least 30 minutes. Because of the time required for frozen section preparation, elderly or incapacitated patients may need an accompanying caretaker who would then need to stay in the procedure room with the patient during the entire procedure rather than sent to a waiting room where social distancing is difficult. Patients can wear a mask and goggles during the operation, provided that the surgical site is accessible.

Truncal/Breast Reconstruction

Although there are a number of breast reconstruction options available following mastectomy, whether with regard to type or timing of the procedure, performing the least resource-intensive procedures during this trying time may be warranted, both to maximize the much-needed supplies to treat COVID-19 patients and to decrease the risk of exposure to patients and health care workers. Plastic surgeons at centers and hospitals are currently weighing options of performing only a form of delayed breast reconstruction at this time (i.e., tissue expander placement) and planning for future autologous options in certain patients. Alloplastic and autologous reconstruction each has its positive and negative points. Although autologous reconstruction is associated with greater patient satisfaction and cost-effectiveness in the long term, it does demand increased

resource use in the form of staffing or supplies, and longer operative time and hospital stay, when compared to alloplastic reconstruction.^{47–49} Of note, operative time may be especially important to consider, given the increased exposure time to hazards such as surgery-induced aerosol generation. Taking into account the more extensive scope for autologous reconstruction, such as with regard to the additional burden of a donor site, there is also the potential for increased surgical complications, which may extend hospital stay and increase exposure. As such, it is our opinion that performing either immediate direct-to-implant reconstruction in patients suited for the procedure or delaying autologous breast reconstruction with placement of tissue expanders instead may be most prudent. Of note, for delayed reconstruction, the decision must also be weighed against risks such as scarring, larger skin paddles, or negative psychological impact, and it is ultimately up to the surgeon to determine the best course of action. Despite the comparatively low exposure to mucosal surfaces and respiratory secretions compared to head and neck reconstruction, there is still the potential risk of surgical instrument-generated aerosol exposure to consider until it has been studied further.

Extremity/Hand Surgery

All precautions regarding prevention of viral transmission and deferring elective hand procedures hold as well during this unprecedented time (e.g., trigger finger release, cyst removal). Although these operative areas do not involve mucosal areas, providers may consider minimizing cautery during procedures by the routine use of tourniquet compression where possible. During emergent cases such as replantation and revascularization, extreme care by all health care workers, especially during intubation and extubation, should be taken. Certain cases may be performed as in a local/regional situation for anesthesia.

COSMETIC SURGERY

Although elective cosmetic surgery constitutes a nonessential service, patients may still call the office for the possibility of office-based surgery or procedures. Although it is at the discretion of the practitioner, during times of a pandemic—especially when a vector is transmitted by asymptomatic carriers—it is recommended to defer not only cosmetic operative procedures but also cosmetic medicine (i.e., fillers, dermabrasion, laser treatments). These recommendations do not include situations that

demand more immediate evaluation or treatment—in particular, the care of perioperative patients from recent procedures requiring procedures such as hematoma evacuation, incision and drainage of infections, acute management of implant exposure, or wound dehiscence. Noninvasive procedures such as CoolSculpting (Zeltiq Aesthetics, a division of Allergan plc, Pleasanton, Calif.) should be deferred also at this time. Specifically, the treatment of epistaxis following rhinoplasty in the office is best treated by the operating physician rather than in the emergency room during the time of a pandemic secondary to the amount of potential exposure to the patient or health care provider in a general emergency room setting. Epistaxis treatment follows the same guidelines as outlined in this article for high-risk aerodigestive tract precautions. Although the explantation of an implant is readily performed in the office, the placement of a sterile implant (e.g., breast implant) in the office is to be very carefully weighed, as various “office” conditions may not have the same sterility rigor as those treated in the operating room.

CONCLUSIONS

The COVID-19 pandemic poses unique challenges for the various disciplines involved in plastic and reconstructive surgery, especially as the situation continually evolves. Proceeding with appropriate personal protective equipment is paramount for health care provider and patient safety; however, additional consideration may be weighed for the avoidance of electrocautery for the potential aerosolization of viral load in the operating room aside from the respiratory tract. Although universal recommendations are difficult because of being patient, physician, and region specific, a thoughtful protocol of assessment and surgical intervention needs to be established based on the individualized pandemic status.

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