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"Slowing the Spread and Minimizing the Impact of COVID-19: Lessons from the Past and Recommendations for the Plastic Surgeon"

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Abstract

Background: COVID-19, a novel coronavirus originating in December 2019 in Wuhan, China, has spread rapidly throughout the globe over 3 months. On March 11, 2020 the World Health Organization declared COVID-19 a global pandemic. COVID-19 represents a nearly unprecedented threat to both the public health and the durability of our healthcare systems and will profoundly affect the field of plastic and reconstructive surgery. The objective of this paper is to provide a natural history of COVID-19 – including virology, epidemiology and transmission patterns – and a guide for plastic surgeons regarding patient and resource management.

Methods: The authors reviewed existing literature regarding COVID-19, both primary research and secondary reviews, via PubMed queries, and recommendations from relevant professional organizations (e.g., American College of Surgeons and American Society of Plastic Surgeons). The literature and recommendations were summarized to provide a specific guide for plastic surgeons.

Results: Internationally, over 5.7 million cases and 357,000 deaths from COVID-19 have been reported at time of writing. No pharmacological treatments have been identified, but epidemiological strategies were identified to prevent viral spread, preserve healthcare resources, and protect patients and surgeons globally. Specific recommendations for plastic and reconstructive surgeons include postponing elective cases and transitioning to telecommunication platforms for patient consultations and education.

Conclusions: COVID-19 represents a nearly unprecedented threat to the public health and the durability of healthcare systems in the contemporary era. While plastic and reconstructive surgery may seem relatively remote from the pandemic in direct patient care and exposure, our field can significantly enhance healthcare resource management.

Starting in December 2019, a series of cases of viral pneumonia emerged in Wuhan, China and quickly propagated within Wuhan and wider China within weeks. The causal agent was isolated in early January 2020 and identified as a β-coronavirus.[1] This newly isolated virus was termed Coronavirus Disease 19 (COVID-19) by the World Health Organization (WHO). Coronaviruses are enveloped single-stranded RNA viruses that cause a variety of animal diseases.[2] Coronavirus can be divided into 4 genera, α/β/γ/δ, all causing animal disease. There are only six previously known coronaviruses that infect humans, all of which fall into the α/β genera. Two of these, SARS-CoV and MERS-CoV, cause Severe Acute Respiratory Syndrome and Middle Eastern Respiratory Syndrome, which are associated with high rates of mortality.[3] Similar to SARS-CoV, COVID-19 uses the ACE2 receptor as its portal of entry into human cells. As high proportions of type I and II lung alveolar cells express ACE2, respiratory tissues are particularly susceptible to infection.[4] Further genetic analysis of COVID-19 has identified bats as the likely host of origin, although several intermediate hosts have been suggested including pangolins and snakes.[1,5]

The symptomatology of COVID-19 mimics that of other respiratory illnesses. COVID-19 spreads through respiratory contacts; however, the virus has been isolated from blood and fecal samples, making transmission through multiple routes a possibility.[6,7] Once exposed, the time to symptom presentation ranges from 1 to 14 days with the average being 3 to 7 days.[8] During this time, the infected individual is contagious despite being asymptomatic.[9,10] The most common symptoms observed are cough, fevers, shortness of breath, and fatigue. Smaller numbers of patients develop headache, diarrhea, and hemoptysis.[11–13] Approximately 20% of patients develop more severe disease requiring hospitalization with subsets of patients developing acute respiratory distress syndrome (ARDS), acute kidney injury, elevated cardiac enzymes, and liver

injury. Patients over the age of 65 or with multiple comorbidities are more likely to develop severe disease.[13–15]

While several drugs are currently undergoing testing as antivirals for COVID-19, data supporting their use is premature.[16] The FDA recently granted emergency authorization for use of hydroxychloroquine for treatment of COVID-19.[17] This authorization has been controversial as the drug remains under investigation for this indication. There are ongoing clinical trials investigating multiple medications and vaccines for the treatment of COVID-19, though deployment of these into the general population is likely months away (**Table 1**).

Disease Epidemiology in 3 Countries

With COVID-19 spreading across the world, understanding the patterns of disease transmission is paramount to minimizing the number of new infections. Interventions thus far have attempted to "flatten the curve" or slow the rate of new cases to prevent overwhelming the capacity of the healthcare system. We can also look to patterns of disease spread in other nations to better inform our response. China, as the country of origin, has now seen its rate of new cases decrease drastically as government-mandated quarantines have taken effect. Italy is currently beginning to see a flattening of the curve, but many remain infected at this time. The US has seen a dramatic increase in case numbers, now with the largest number of cases worldwide, as the pandemic has spread to almost every country in the world (**Figure 1**).[18] Current epidemiology data is updated daily at the World health Organization website (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports).

China: The initial cluster of COVID-19 infected patients was linked to a seafood and wet animal market in Wuhan, a city in the Hubei province of China, suggesting the zoonotic origin.[19,20] By December 29, 2019 only 5 hospital cases of COVID-19 had been identified within

Wuhan, but this number quickly grew to 571 confirmed cases across 25 Chinese provinces by January 22, 2020. Geometric growth in disease transmission followed, and by January 30, there were a total of 7734 confirmed cases.[21] A confluence of factors likely allowed COVID-19 to spread so rapidly within China. Wuhan, the most populous city in central China (11 million) serves as a significant transportation hub. Additionally, outbreak of the virus coincided with the Chinese Lunar New Year, a period during which many people travel, which facilitated dissemination of the disease.[22] An analysis of the first 425 cases by Li et al., found the initial doubling time of cases to be 7.4 days, with each patient infecting 2.2 others, on average.[6] Other sources estimate the doubling time to be 5.2 days immediately before Wuhan was quarantined and the symptomatic case fatality rate to be 1.4% at that time.[23]

In response to the epidemic, the Chinese government implemented severe lockdown measures on January 23, 2020. Travel to and from Wuhan and other cities within Hubei was suspended. Soon, quarantines and social distancing measures went into effect, with 760 million individuals confined to their homes. From a peak of several thousand new cases per day on January 25, the rate of new cases dropped drastically. Within one week of the restrictions, the daily reproduction number dropped to 1.05.[24] A statistical analysis by Lai et al. predicts that without the measures implemented in China, there would likely have been a 67-fold increase in case numbers. Additionally, they estimate that cases could have been reduced by 66%, 85%, and 95% had measures been introduced one, two, or three weeks earlier, respectively.[25] Another study by Tian et al. found the most effective interventions to be suspending public transport, closing entertainment venues, and banning public gatherings.[26]

Italy: Italy is distinguished epidemiologically by being one of the countries with the highest disease mortality rates. What became the first confirmed case of COVID-19 in Italy was admitted to a hospital in Lombardy on February 20, 2020 with atypical pneumonia.[27] Within 24 hours, an additional 36 cases were identified without definitive links to the first patient, making it clear that COVID-19 had already been propagating within the country.[28] Since then, the growth of cases has occurred in an exponential fashion. As of April 13, 2020, 156,363 people had been infected and 19,901 had died with a case fatality rate estimates ranging from 7.2%-12.7%, with deaths most prevalent among the elderly.[27,29–31]

Despite possessing a robust healthcare system with 3.2 hospital beds per 1000 people, compared with 2.8 per 1000 people in the US, Italy has seen one of the highest death rates thus far.[32] The country has 5200 intensive care beds and in many towns and cities, healthcare systems are strained to the breaking point.[29] With initial quarantine measures placed in Lombardy on March 8 2020, and soon after extended to the country as a whole, Italy has seen a reduction in daily new cases, with under 1000 daily new cases reported during much of May.[31] Facing healthcare shortages, the Italian government has made efforts to significantly increase ventilator production and recalled doctors from retirement to meet demands.[33]

The United States: The COVID-19 crisis has evolved so that the United States now has the largest number of cases world-wide. The first American case was identified in Washington state on January 19, 2020 as a 35 year-old man with history of recent travel to Wuhan.[34] COVID-19 cases have since been confirmed in all 50 states and Washington DC as well as multiple US territories. As of May 29th, there have been over 1.6 million cases with 98,889 deaths in total.[31] The largest case cluster has been in New York with over 368,000 cases and a majority of those in New York City (203,778 cases, 21,477 deaths).[35,36] Large case clusters have also been reported

in several other states including New Jersey, Michigan, and Louisiana with thirty states reporting greater than 10,000 cases at time of writing.[35] Case fatality estimates in the US have ranged between 1.8 and 3.4%, with the University of Oxford reporting 3.4%, although these are likely to change as more suspected cases are tested.[30,38] Some estimates have predicted as high as 240,000 deaths in the United States although more recent data suggests closer to 130,000 cumulative deaths through August with an estimated maximum of 180,000 deaths.[37] Of those infected, patients over 85 years of age and those with comorbidities have the highest case fatality rate.[30,38]

The response to COVID-19 has varied on a state-by-state basis. Significant international travel bans to and from both Europe and Asia have been imposed to curb the importation of new cases. Many American States have issued "shelter in place" orders, restricting all non-essential travel and effectively confining individuals to their houses. However, this level of restriction has not been uniformly applied across states. Comparatively, both Italy and China had imposed nationwide restrictions by this time-point following their respective first cases.

Lessons from the Past and Recommendations for the Plastic Surgeon

Although the COVID-19 pandemic is rapidly becoming the worst global health emergency of our time, it is not unprecedented. Most analogous to the current global pandemic is the 1918 Spanish Flu pandemic. During 1918-1919, an H1N1 Influenza A virus swept across the globe infecting a third of the world's population and killing an estimated 50-100 million people during the first year of the pandemic. On average, the case fatality rate in the US was estimated at 0.5-1%; however this rate was found to be much higher in crowded urban areas with poor hygiene and was estimated at greater than 2.5% internationally.[39,40] Even between cities, there was great variability between infection rate and case fatality rates, providing valuable insight into how timely interventions can affect the course of disease spread and mortality.

Both Philadelphia and St. Louis were hit by the pandemic; however, their responses were drastically different. Philadelphia had its first reported case of Spanish Flu on September 17. Unfortunately, no interventions were made to limit disease spread until October 3, 1918. In fact, a war bonds parade was held September 28, drawing crowds numbering 200,000 people.[41] Within 4 weeks, Philadelphia had 47,000 cases and 12,000 deaths, of a population of 1.7 million, earning it the highest death toll in the US.[42] Conversely, St. Louis imposed restrictions on social gatherings two days after cases first appeared in the city. The final death toll in St. Louis was approximately 700, with a significantly decreased curve of disease spread.[41] Historical evidence clearly supports the efficacy of non-pharmacologic interventions to limit exposure and slow spread.

COVID-19 and Management of Surgical Systems

As the number of Covid-19 cases requiring evaluation and hospitalization has rapidly increased throughout the United States, so too has the demand for medical supplies, including ventilators, critical support equipment, and personal protective equipment. Based on our review of the primary literature, current professional society recommendations, and recommendations from individual hospital systems, we propose the following strategies for practice modification to maximize the beneficial impact of our field during the Covid-19 Pandemic.

1. Postpone all elective operations and minimize OR time and hospital time for patients whose surgeries cannot be postponed

To help guide surgeons in triaging operations that can safely be postponed to relieve the burden on our healthcare system, the American College of Surgeons (ACS) espouses the use of the Elective Surgery Acuity Scale (**Table 2**).[43] This triaging system, as well as frequently updated recommendations from the American Society of Plastic Surgeons (ASPS), is particularly

helpful for plastic surgery, where the majority of cases are elective by nature.[44] In 2018, 17.7 million cosmetic procedures (both surgical and non-surgical) and 5.8 million reconstructive procedures were performed in the United States. Based on the ACS Elective Surgery Acuity Scale and per recommendations of ASPS cosmetic procedures should be postponed through the COVID-19 pandemic.[44] Additionally, complex reconstructive surgeries use valuable hospital resources such as ventilators and often require extended hospital stays. Broadly, reconstructive cases can be divided into those performed for salvage/wound closure purposes and those performed for quality of life purposes. Examples of the former category include soft tissue reconstruction for limb salvage, reconstruction of extirpative defects where reconstruction in necessary for surgical closure, and traumatic/infectious interventions. The latter category includes breast and pressure sore reconstruction.

Salvage/wound closure procedures often cannot be postponed due to coordination between multiple teams and to necessity of preserving life and limb. Although there is now data to support delaying traumatic lower extremity reconstruction beyond the original 3-day window proposed by Godina, it is still recommended to perform reconstruction within 10 days. Providers should consider negative pressure wound therapy for traumatic wounds when reconstruction is not possible due to patient factors or hospital resources.[45–47] In those situations where cases cannot be delayed, testing for COVID-19 should be performed in the preoperative period. Any patients not able to be tested prior to surgery should be treated as a suspected COVID-19 case.

Additionally, the World Federation of Societies of Anesthesiologists recommends minimal health care workers present in the operating room during intubation of suspected or confirmed COVID-19 patients with stringent PPE requirements for those present with N95 masks and face shields or PAPR with gowns and gloves.[48]

Reconstructive surgeries performed for quality-of-life purposes perhaps prove the most difficult to triage. Breast reconstruction comprises a large portion of plastic reconstructive surgeries performed yearly. Utilization of hospital resources varies greatly based on the type of reconstruction performed. Autologous breast reconstruction is possibly one of the most resource-heavy surgeries commonly performed by plastic surgeons. These operations, when performed in concert with mastectomies, can require 6-10 hours in the operating room and, on average, require hospital stays of 3-5 days, while alloplastic-based reconstruction is associated with shorter operative times and hospital stays.[49–51] The ASPS now recommends delaying all autologous breast reconstruction and evaluating alloplastic reconstruction on a case-by-case basis. Final case determination should be made based on hospital resource demand, and patient factors that potentially increase resource requirements.[52] Other reconstructive cases including chronic lower extremity wounds and pressure ulcers should be delayed when there is no immediate risk to patient health or limb. Instead, close follow-up with outpatient wound clinics, when available, should be arranged. Extirpative surgeries such as head and neck surgery often require immediate reconstruction. **Table 3** provides a listing of Plastic Surgery procedures and recommended triage practices.

Unfortunately, as the COVID-19 situation and response continue to change rapidly, it is difficult to assess the length of time these restrictions will need to remain in place. A return to normalcy should be dictated by governmental health organizations such as the CDC as well as professional societies in conjunction with hospital entities. The economic impact of these restrictions must be duly balanced against the risk of creating a secondary surge of cases.

2. Triage clinic appointments. Whenever possible, conduct through electronic media, limiting in-person appointments to urgent visits

In addition to minimizing hospitalization time for patients, we should consider mechanisms by which we can reduce clinic volumes. There is already some evidence that for non-urgent consultations, patients prefer telemedicine to face-to-face clinic appointments.[53] We propose triaging clinic appointments in a manner similar to those systems already in place for patient calls. New patient appointments, if feasible, should be delayed. Postoperative visits, when no suture/drain removal is required, should be conducted via telehealth. Only urgent appointments should be relegated to face-to-face interaction. This includes patients requiring suture/drain removal, those with concerns for new/worsening wounds, concerns for infection not responsive to initial oral therapy, and traumatic injuries/fractures where telehealth limits examination. The CDC recommends observation of social distancing in clinical settings including designated clinic areas for patients with respiratory symptoms, barriers between patients and reception desk workers, and placement into private clinic rooms with closed doors.[54] Additionally, providers should wear PPE including a minimum of face-masks and face-shields for all patients and N95s/PAPRs, face-shields, gowns and gloves for patients with respiratory symptoms. High-risk office procedures including those requiring close proximity to the respiratory tract should be performed with full PPE including N95s/PAPRs, face-shields, gowns and gloves.

In anticipation of eventual resumption of normal practice, it is also conceivable to begin consultations for elective matters via telemedicine tools. In one study, Hwang et al. found success for initiating interactions for oculoplastic surgeries via one such method.[55]

3. Limit departmental/divisional meetings; cancel or transition grand rounds to electronic formats

While grand rounds, journal clubs, and lab meetings represent key educational activities at many institutions, they also require gatherings that violate the principles of social distancing. As there is a plethora of technology (both free and for pay) available to allow for teleconferencing, current recommendations are to switch to a virtual platform for all educational activities until recommendations requiring social distancing are lifted. There is a large wealth of educational material available online on the American Society of Plastic Surgeons Education Network website (https://ednet.plasticsurgery.org/). This can be used to continue and further develop resident curricula. Additionally, screen sharing technologies allow for ongoing staff and resident presentations and indications conferences. We recommend increasing the number of weekly conferences in divisions/departments where most residents and staff are isolated. This allows not only for expansion of indications conferences and curricula, but also the introduction of weekly "touch in" conferences for free form discussions of issues arising during the pandemic and the potential untoward effects of "sheltering at home" including burnout, family and self-care, and provider safety.

4. Limit provider time/exposure to the hospital, develop modified call systems, and maintain "clean" pools of residents

With the anticipated reduction in case volumes, there should be a commensurate reduction in staffing of plastic surgery services. Call systems minimizing the number of residents in a hospital at any given time are paramount. Additionally, consults should also be triaged to minimize the number seen in face-to-face interactions. While there are many situations in which specialty care is needed, we must work with our colleagues requesting consultation to establish

the timescale during which a patient must be seen and whether face-to-face consultation is necessary. To this end, we recommend designating certain providers as responsible for triaging consults. In our hospital, the senior craniofacial staff has been designated as the consult triage provider for craniofacial trauma. All new consultations of this nature are first discussed with this staff prior to being seen in the hospital. They then determine if patients need to be seen immediately, later in inpatient admission once COVID-19 screening/testing is completed, or on an outpatient basis. Similar triage systems can be established for hand and reconstructive consultations. To further maintain and protect our workforce, we have partitioned the resident and faculty cadre into "pods" consisting of limited faculty and 4 residents. Each pod consists of the following: a senior resident and a junior day resident, both of whom are responsible for rounding, covering non-elective cases, and seeing consults. Additionally, there is a reserve junior resident available for overflow cases and consults. Nights are covered in a night-float system by an intermediate-level resident. Pods are rotated every five days and as needed for provider well-being. This system minimizes resident exposure and ensures there are well-rested residents available as needed.

5. Redeploy faculty and residents across the hospital as needed for coverage

Many hospitals are experiencing unprecedented surge in patient volumes due to the COVID-19 coverage. Simultaneously, as plastic surgery case-loads fall, demands on inpatient plastic surgeons and residents have decreased. These providers should be viewed as additional resources for coverage in different units across hospitals. In our hospital system, residents and staff across specialty services have been redeployed to COVID-19 units that can be activated should demand require it. Additionally, our providers are also working in intensive care settings to contribute to patient care. Although such coverage settings may be outside of our normal work

patterns, the COVID-19 pandemic is an unprecedented situation requiring that all healthcare providers contribute to the response effort.

6. Provide supportive structures to monitor for physician burnout and encourage symptom reporting

The unfortunate reality of the current pandemic is that healthcare workers are in particularly vulnerable positions. With exposures likely for the average healthcare worker, it is our responsibility to frequently self-monitor for symptoms and self-quarantine should we develop them. At a time where physician burnout is also increasing it has also never been more important for us to monitor each other for signs and symptoms of burnout.[56] In addition to the scheduled educational conference time discussed above, we recommend placing an emphasis on the importance of "virtual" social time. We have implemented semi-scheduled social time and several residents and staff across our division have taken to hosting online social hours on an approximately weekly basis.

Conclusions

COVID-19 represents an unprecedented threat to our healthcare system and economy, that has not been seen for a century. Conditions are continuing to change rapidly, and uncertainty regarding the pandemic, and our clinical practice remains high. Both the responses of other countries and history provide us tools to respond to this pandemic. As plastic surgeons, we have a responsibility not only to treating our patients, but to limiting their and our own infectious contagion exposure. Unfortunately, this duty will take the form of an unavoidable decrease in case volumes, likely for several months; however, available technology provides methods through which we can continue to safely provide care. Additionally, we can contribute to the treatment of patients through redistribution across hospital systems where the need is greatest.

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Figure Legends

Figure 1: World map of daily average newly reported cases of COVID-19 infections, data averaged over 7 days as of 5/29/2020. Data used to generate map taken from European Centre for Disease Control and Prevention (ECDC) and map generated using Google geocharts. Up to date information regarding case and death numbers can be found at the websites for the CDC, WHO, ECDC, and Johns Hopkins University.

Medication and Class	ClinicalTrials.Gov Identifier
Established Anti-Viral Medications	
Favipiravir	NCT04336904
Lopinavir/Ritonavir	NCT04321993
Remdesivir	NCT04292899, NCT04292730, NCT04323761, NCT04280705
Biologics	
Baricitinib	NCT04340232
Mavrilimumab	NCT04337216
Sarilumab	NCT04315298
Tocilizumab	NCT04331795, NCT04320615
Vaccines and Immune Therapies	
Convalescent Plasma	NCT04338360
DNA Vaccine	NCT04336410
mRNA Vaccine	NCT04283461
Other Drugs of Interest	
Azithromycin	NCT04332107
Colchicine	NCT04322682
Hydroxychloroquine/Chloroquine	NCT04329923, NCT04318444, NCT04341441, NCT04334967, NCT04342169, NCT04328961,

	NCT04333654, NCT04328467, NCT04332991, NCT04333732, NCT04308668
Hydroxychloroquine and Azithromycin	NCT04334512, NCT04329832, NCT04334382, NCT04336332, NCT04335552, NCT04341727
Hydroxychloroquine and Vitamin C, Vitamin D, or Zinc	NCT04335084
Losartan	NCT04335123, NCT04312009, NCT04311177, NCT04340557
Nitric Oxide	NCT04305457, NCT04306393
Tranexamic Acid	NCT04338074, NCT04338126

Table 1 – Current therapeutics and vaccines under investigation for COVID-19

Table 2 – Elective Surgery Acuity Scale (Source: American College of Surgeons)

Tiers/Description	Definition	Locations	Examples	Action
Tier 1a	Low acuity surgery/healthy patient Outpatient surgery Not life-threatening illness	HOPD ASC Hospital with low/no COVID- 19 census	Carpal tunnel release Penile prosthesis EGD Colonoscopy	Postpone surgery or perform at ASC
Tier 1b	Low acuity surgery/unhealthy patient	HOPD ASC Hospital with low/no COVID-19 census		Postpone surgery or perform at ASC
Tier 2a	Intermediate acuity surgery/healthy patient Not life threatening but potential for future morbidity and mortality. Requires in hospital stay	HOPD ASC Hospital with low/no COVID-19 census	Low risk cancer Non urgent spine Ureteral colic	Postpone surgery if possible or consider ASC
Tier 2b	Intermediate acuity surgery/unhealthy patient	HOPD ASC Hospital with low/no COVID-19 census		Postpone surgery if possible or consider ASC

Tier 3a	High acuity surgery/healthy patient	Hospital	Most cancers Highly symptomatic patients	Do not postpone
Tier 3b	High acuity surgery/unhealthy patient	Hospital		Do not postpone

Procedure	Classification	Recommendation
Cosmetic Surgeries/Procedures	Elective	Postpone
Chemodenervations		
Fillers		
Lasers		
Chemical Peel		
Augmentations		
Breast Reduction		
Mastopexy		
Facial Cosmetic Surgeries		
Reconstructive Surgery – Quality of Life Procedure	Elective and Semi-Elective	
Autologous Breast Reconstruction		Convert to alloplastic or postpone
Alloplastic Breast Reconstruction		Proceed if no significant increase in hospital resources
Breast Implant Removal		Postpone
Pressure Sore Reconstruction		Postpone if patient/wound stable
Hernia Repair		Postpone if no incarceration
Scar Revision		Postpone
Maxillofacial (Congenital)		Consider postponing if no impediment to airway or alimentation

Hand Surgery – Nerve Decompressions,		Postpone if no imminent threat to function
Selected Fractures		
Chronic wound reconstruction		Postpone if no imminent threat to life or limb
Reconstructive Surgery – Trauma and Salvage	Semi-Elective, Urgent, Emergent	Proceed with surgery/procedure
Limb Salvage – Including Microsurgery		
Head and Neck Reconstruction		
Laceration Repairs		
Burn Cares		
Hand Surgery – Trauma, Tumors, Nerve Transfers, Tendon Transfers, Microsurgery		
Pelvic/Abdominal Wall Reconstruction – Cancer		
Skin Cancer Excisions		

Table 3 – Plastic Surgery COVID-19 Case Triage Recommendations

Figure 1