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# Emergency Hand and Reconstructive Microsurgery in the COVID-19–Positive Patient

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The case spectrum in hand surgery is one of extremes—purely elective day surgery cases under local anesthesia to mangling limb injuries that require immediate, and frequently, lengthy, surgery. Despite the cancellation of most elective orthopedic and plastic surgical procedures, hand surgeons around the world continue to see a steady stream of limb-threatening cases such as severe trauma and infections that require emergent surgical care. With the increase in community-spread, an increasing number of COVID-19–infected patients may be asymptomatic or have mild, nonspecific or atypical symptoms. Some of them may already have an ongoing, severe infection. The time-sensitive nature of some of these cases means that hand surgeons may need to operate urgently on patients who may be suspected of COVID-19 infections, often before confirmatory test results are available. General guidelines for perioperative care of the COVID-19–positive patient have been published. However, our practices differ from those of general orthopedic and plastic surgery, primarily because of the focus on trauma. This article discusses the perioperative and technical considerations that are essential to manage the COVID-19 patient requiring emergency care, without compromising clinical outcomes and while ensuring the safety of the attending staff. (*J Hand Surg Am.* 2020;45(9):869–875. Copyright © 2020 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

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**C** COVID-19 HAS DISRUPTED ALL ASPECTS of routine life, with the health care industry at the forefront of this raging pandemic.<sup>1,2</sup> Many centers around the world have cancelled elective and

nonurgent orthopedic and plastic surgical procedures to protect health care workers and patients, as well as to conserve hospital resources. However, in many places, surgeons continue to see a steady stream of limb-threatening cases that require emergent surgical care, mainly because some key industries (eg, construction; oil and gas) continue to function. It is neither practical nor ethical to defer such cases. With the increase in community spread, an increasing number of infected patients may be asymptomatic<sup>3</sup> or have mild, non-specific or atypical symptoms.<sup>4</sup> Some of them may already have an ongoing, severe infection. The time-sensitive nature of some of these cases means that hand surgeons may need to operate

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urgently on patients who are suspected of COVID-19 infections, often before confirmatory test results are available. General guidelines for the perioperative care of COVID-19—positive patients have been published.<sup>5</sup> However, hand surgeons face additional challenges, primarily because of our focus on trauma. This article outlines some specific perioperative and technical considerations in the management of COVID-positive patients with urgent, limb-threatening conditions that seek to avoid compromising clinical outcomes while ensuring the safety of the attending medical staff.

### PATIENT DEMOGRAPHICS AND RISKS FACTORS

The main hand and upper limb conditions that require immediate surgical care are severe open injuries, infections, and less commonly, bleeding/fungating tumors. Open fractures, tendon injuries, and ligament injuries also need to be addressed early. Infections tend to occur in the elderly with compromised immunity (eg, diabetes, chronic steroid treatment), comorbid illnesses (eg, renal impairment), and decreased physiological reserves (eg, heart disease). There is evidence that the elderly with pre-existing conditions have the highest risk of mortality from COVID-19.<sup>6,7</sup> High-energy trauma tends to occur in young, physically fit males engaged in manual work or who are injured in motor vehicle accidents. These patients are less likely to succumb to COVID-19,<sup>8</sup> but there are 2 issues that are important to recognize. First, there may be a subset of young and fit individuals more prone to a severe form of acute lung injury secondary to COVID infection, possibly owing to an overactive immune response.<sup>9</sup> These patients may appear well initially but may deteriorate rapidly. The second issue is pertinent to our local context. Many of the patients with severe hand injuries are migrant manual workers who tend to be housed in dormitories. The close proximity of individuals in these shared living spaces has resulted in several clusters of COVID infection within these communities.<sup>10</sup> Many of these individuals remain asymptomatic or are mildly symptomatic and, therefore, relatively fit to work. Consequently, surgeons managing emergencies in this group of patients have had to assume they were COVID-positive until the results of definitive tests are known.

### PREOPERATIVE CONSIDERATIONS AND PLANNING

The principles of surgery in a COVID-positive patient is akin to wartime surgery, where surgical triage,

thorough rationalization of resources and time efficiency are crucial.<sup>5</sup> The overarching principles in managing COVID-positive patients are (1) ensure the safety of the medical team at all times, (2) prioritize life over limb, (3) do the minimum necessary limb-saving procedure, (4) minimize repeated operations during the contagious period, and (5) defer all other procedures until the patient has recovered from the acute viral infection. Some operations (eg, major limb replantations) place the highest demand on the patient and the medical team. A multidisciplinary approach involving the patient, surgeon, anesthesiologist, and intensivist must be taken to ensure the risks are justified. The decision to proceed also depends on the specific indications, complexity of the procedure, resources required, and whether a viable alternative can be employed at a later stage, such as corrective osteotomy for malunited fractures. Nevertheless, some of the immediate procedures required are time-consuming and resource-intensive, and a departure from the standard principles may be necessary.

### MANPOWER AND RESOURCES

The COVID-19 pandemic has compelled us to re-examine our manpower distribution and routine workflows. We have reorganized our department into 2 self-reliant teams, each comprising 2 or 3 attending surgeons, 2 senior residents or fellows, and 2 junior doctors, that remain physically segregated while continuing to manage patients in the outpatient clinics and operating room. The daily emergency admissions remain high and it is taxing for the entire team to be on call for several days at a stretch. Therefore, each team takes 24-hour emergency calls on alternate days. An attending, senior resident/fellow and junior doctor from that team is responsible for any emergency in that 24-hour period. To illustrate this, team A may take call on Monday, Wednesday, Friday, and Sunday of a particular week. Senior resident 1 in team A takes call on Monday and Friday whereas senior resident 2 is on duty on Wednesday and Sunday. This ensures that each doctor is not on duty more frequently than a 1-in-4 schedule. There are several other advantages to this model in which clinicians are separated spatially. First, each team manages every aspect of a patient's care, ensuring continuity in complex cases. Second, it ensures that there are contingency plans if 1 or more members of a team is exposed to COVID and must be quarantined for 14 days. Third, this model allows senior surgeons to work together on complex surgical procedures to maximize efficiency, facilitate intraoperative decision



**FIGURE 1:** **A** A 26-year-old man, who does manual labor, with suspected COVID-19 infection sustained a clean-cut amputation of the ring finger at zone I. The patient had a positive contact history and had mild upper respiratory tract symptoms. He indicated a strong desire for digital replantation rather than a revision amputation. After appropriate clinical assessment by the on-call hand surgery team, the patient was evaluated by the anesthesiologists to determine fitness for surgery. A nasopharyngeal swab for COVID was taken in the emergency room. **B** The amputated part was examined in a separate room while the patient was being prepared for surgery, and the critical structures were tagged. The digital replantation was performed in a negative-pressure operating room custom-fitted to manage COVID-positive cases. The surgeons took rigorous airborne precautions during parts of the operation where there was a risk of aerosolization, such as bone fixation. The arterial and venous anastomoses were performed wearing face shields to protect the eyes from inadvertent splash while allowing good visualization through the microscope. **C** The digital replant was performed successfully. Bone fixation was achieved using an axial K-wire and interosseous wiring. A single digital artery and 2 dorsal veins were repaired. The patient was isolated after surgery until the swab results were known. He tested negative for COVID and was subsequently discharged from inpatient care 5 days later.

making, and take breaks during long procedures. As much as possible, however, we advocate minimizing the number of medical staff in the operating room and the most senior surgeon must be in attendance for difficult cases.<sup>5</sup> Our model allows us to keep post-call days free of most scheduled activity, so that the team can manage patients from a busy call the day before.

To conserve resources, we employed a calibrated approach to nonessential work, tailored to the severity of the COVID-19 situation locally. In the earlier phases, we cancelled elective, complex surgery requiring inpatient hospitalization (eg, brachial plexus reconstruction) and continued with ambulatory cases under local anesthesia. We further reduced such surgery because of a greater demand for manpower elsewhere. We have also concentrated our 24-hour emergency microsurgery service to a single hospital rather than spread resources more thinly across several affiliated institutions.

### OPERATING ROOM SETUP AND EQUIPMENT

Specific patient transfer, anesthetic, and operating room protocols for COVID-19–positive patients have been described in detail.<sup>5</sup> The current recommendation for surgery on COVID-positive patients is the use of full personal protective equipment (PPE). This includes surgical cap, goggles, gowns, gloves, N95 masks, and shoe covers.<sup>5,11–13</sup> In addition, a powered air-purifying respirator (PAPR) should be

used when an aerosol-generating procedure, such as drilling/sawing, is anticipated.<sup>5,14</sup> This is reasonable for short procedures, but is extremely taxing for operations that extend beyond 3 to 4 hours. It is also impossible to use the operating microscope with a full PAPR setup. We use high-magnification loupes ( $3.5\times$ – $4\times$ ) with PAPR suits for procedures involving medium-sized vessels (eg, radial artery repair). For procedures mandating the operating microscope (eg, digital artery repairs), the surgeon will have to remove the PAPR and wear goggles or a faceshield instead. It is important that all parts of the surgery that potentially generate aerosols should be completed before transitioning to the operating microscope (Fig. 1). In this context, the surgeon must consider the patient's needs and do what they can while protecting themselves. For example, we should not perform noncritical arterial repairs in a viable digit because the risks do not justify the benefits. More critical problems such as single-finger replantation may create an ethical dilemma.<sup>15</sup> Finally, we are relying increasingly on small, purpose-built lead-lined procedure rooms to perform semi-urgent procedures such as fracture fixation, so that main operating room resources are not taxed.

### ANESTHESIA

The current guideline for anesthesia in COVID-positive patients is to minimize aerosolization.<sup>14,16</sup>

Fortunately, many hand and upper extremity procedures can be performed under local or regional anesthesia augmented with sedation, obviating the need for general anesthesia (GA)<sup>17,18</sup>. This minimizes the risk of COVID-19 aerosolization from intubation. We have adapted some aspects of the WALANT (wide-awake, local anesthesia, no tourniquet) technique<sup>19</sup> to our current situation and describe its application to specific situations in the next section. Other organizations have similarly adopted this approach for elective and emergency hand surgery during the pandemic.<sup>20</sup>

## SPECIFIC TECHNICAL CONSIDERATIONS

### Limb-threatening trauma

This category includes amputations, extensive soft tissue injuries requiring critical revascularization, and compartment syndrome requiring fasciotomy. As outlined previously, certain decisions must be rationalized thoroughly. We normally offer single-digit replantation in clean-cut amputations in which the outcomes are expected to be favorable. However, the risks in a COVID-positive patient may not be justified and a revision amputation may be the safest option. Definite indications for replantation in the current context include thumb and multiple-finger amputations as well as transmetacarpal and more proximal amputations.

We use a nerve block that must include the medial arm (supplied by the intercostobrachial nerve) so that a tourniquet can be used to minimize blood loss. The added benefits of regional blockade are sustained postoperative pain relief<sup>21</sup> and peripheral vasodilation (for microvascular procedures).<sup>22</sup> The surgical priorities for complex trauma remain and include thorough debridement, immediate skeletal stabilization, revascularization, and adequate soft tissue cover. Skeletal fixation must be fast and reliable, and the surgeon should avoid tedious external fixators and internal devices. For digital replantation, we place a sleeve cut out from a latex glove around the bone end while inserting 1 or 2 K-wires. This was originally described to prevent entangling adjacent blood vessels during pinning,<sup>23</sup> but in this context, it is a method to minimize aerosolization. For larger bones (eg, metacarpals), we prefer to use a single, 1.4-mm axial K-wire to maintain length and provide relative stability. We also advocate immediate vein grafting when the prospect of success with primary vessel repair seems low, such as in situations in which there is a wide zone of injury and the vessels are of uncertain quality. Finally, the surgeon must also

determine whether definitive soft tissue cover is essential. Wounds amenable to skin grafting, such as exposed healthy muscle, should be covered at the index surgery to avoid additional surgery. Defects requiring flap coverage can be managed with negative-pressure dressings until the patient can be deisolated. In extenuating circumstances, banking of amputated parts (eg, ectopic banking; cryopreservation) and delayed replantation may be considered, although we have limited experience with this.<sup>24–26</sup>

### Infections

Severe, spreading infections such as necrotizing fasciitis should be treated as surgical emergencies and the patient must be brought to the operating room as soon as possible. Other infections such as paronychia, deep space abscesses, and flexor tenosynovitis should ideally be addressed within 4 to 6 hours. We use local anesthesia (eg, digital/wrist block) for localized infections such as paronychia and finger abscesses and regional anesthesia for extensive or deeper infections. Incisional epinephrine may further compromise the digital and cutaneous circulation and is not recommended in these settings. The goals of surgery are to decrease the microbial burden and minimize the number of subsequent procedures. To this end, radical debridement may be beneficial, where even tissue of questionable viability is excised, so that subsequent surgery may be delayed or avoided altogether. Sharma et al<sup>27,28</sup> identified risk factors predicting persistence of infection and the need for repeated debridements. There are similar criteria for specific infections such as flexor tenosynovitis<sup>29</sup> and necrotizing fasciitis.<sup>30,31</sup> These criteria enable hand surgeons to identify patients with a poor prognosis, particularly in the setting of an established COVID infection, and early amputation may be considered rather than attempting repeated efforts at digit or limb salvage. In the current setting where operating room resources are limited, we drain localized infections (eg, paronychia) in the ward or an ambulatory facility. Hyatt and Saucedo<sup>32</sup> have indicated procedures that may be safely performed at the bedside, taking into consideration the patient's physical and mental state, severity of the condition, and the resources available. Definitive soft tissue reconstruction should be deferred, and interim negative-pressure dressings may help postoperative wound care and nursing requirements.

### Open fractures, tendon, nerve, and ligament injuries

Open wounds with underlying noncritical injuries (eg, nerve, tendon, bone) should be thoroughly

cleaned with the patient under an appropriate block and sterile dressings applied. These procedures may be performed in the emergency room and further tests to ascertain the patient's COVID status should be obtained.<sup>5</sup> In the COVID-positive patient, any further surgery must be kept to a minimum. The emphasis must be to convert extensively contaminated wounds to clean surgical wounds. These procedures can be performed with the patient under local or regional anesthesia. All other closed injuries (eg, distal radius fractures) should be reduced and treated in a thermoplastic/plaster orthosis while the patient recovers. An exception to this is when severely displaced fractures cause impending skin, neurological, or vascular compromise.

The definitive repair or reconstruction of these injuries should be deferred until after the patient has recovered from the acute viral infection. As far as possible, we prefer to do this under WALANT rather than GA, even though the patients are presumably no longer contagious by this time and aerosolization during intubation does not pose a risk to the medical team. There is evidence that COVID-19 infection damages lung parenchyma and the resulting pulmonary fibrosis decreases lung compliance.<sup>33</sup> It is likely that the risks of GA will be higher in the immediate period after recovery from COVID-19. We use a combination of lidocaine/bupivacaine nerve blocks and additionally infiltrate the planned incision site with a mixture of lidocaine and epinephrine. This allows the procedure to be done comfortably in a bloodless field without a tourniquet. Some complications from delaying surgery (eg, tendon retraction, soft tissue scarring) will be inevitable and the surgeon must be prepared to formulate a staged reconstructive plan, such as scar excision and primary resurfacing followed by tendon grafting.

### Immediate soft tissue reconstruction

Definitive soft tissue coverage should be delayed as much as possible in the COVID-positive patient because these procedures are time consuming and impose a strain on limited resources. In specific situations in which urgent soft tissue reconstruction is necessary (eg, mangling hand injuries with exposed vascular repairs), we recommend soft tissue coverage options that are quick and reliable, in lieu of more complex flaps that may have better functional and aesthetic outcomes. In the upper limb, we recommend using the pedicled radial artery or reverse radial artery forearm flap for coverage of small to medium defects and the groin flap for large defects.<sup>34</sup> Finally, emergency free flaps should only very rarely be necessary

to provide concomitant soft tissue coverage and revascularization.

### POSTOPERATIVE CONSIDERATIONS

Any COVID-positive patient who has undergone a major procedure should be nursed in a high-dependency unit or intensive care unit.<sup>5</sup> However, the nursing staff may not be familiar with some of the specialized requirements (eg, monitoring replantations and flaps), and the mandatory use of PPE may hamper frequent bedside monitoring. There should be clear verbal and written communication between the surgical and the nursing teams. Some adjuncts facilitate clinical monitoring. We create a generous window in the bandages and use clear adhesive dressings to monitor revascularized tissue from a distance. Clearly placed labels are used to indicate areas where pressure should be avoided (eg, over vascular pedicles). We also use digital devices to monitor temperature and blood flow remotely. A pulse oximetry probe providing continuous data on oxygen saturation and pulsatile blood flow is applied to the pulp of replanted digits. We suture surface electrodes to flaps and an adjacent control site so that they can generate continuous, real-time data on regional temperatures. These measures minimize the need for frequent direct patient contact.

Several pharmacological issues deserve attention in COVID-positive patients who have recently undergone emergency upper limb surgery. We routinely use high-volume fluid regimens after replantations and free flaps. This must be carefully titrated in the patient with acute interstitial lung injury and may require invasive monitoring (eg, central venous pressure lines) to prevent fluid overload and pulmonary edema. Some patients may require inotropes for their general medical condition and the surgeon must recognize that this may inevitably have a negative impact on the outcomes after a microvascular procedure. Pharmacological prophylaxis against deep venous thrombosis must be carefully balanced with the risks of bleeding and subflap hematoma that may compromise the circulation. There is increasing evidence that COVID-19 may induce a hypercoagulable state<sup>35</sup> and Schultz and Wolf<sup>36</sup> reported on 2 COVID-19 patients with digital ischemia. This is likely multifactorial due to thromboinflammation, embolism, use of inotropes, and a vascular steal phenomenon in patients on extracorporeal membrane oxygenation. Digital ischemia portends an overall poorer prognosis and could also adversely affect recovery of the primary hand condition. The authors

suggested a multimodal approach including judicious use of anticoagulants, warming, topical nitroglycerin, and close observation.<sup>36</sup> Finally, an important measure to reduce opioid requirements—and associated problems like respiratory depression—is placing indwelling anesthetic blocks for continuous pain relief. There is increasing concern about the shortage of opioids because of the increased demands in ventilated COVID-19 patients.

### WHAT ABOUT THE NEAR FUTURE?

An issue that many health care institutions are now starting to address is the surge of surgical cases that is anticipated once the acute curve of the pandemic starts to settle. There is no clear indication when the current situation will abate or whether there will be a second wave. Worse still, some infected patients may even be reinfected and display a persistent positive status for a prolonged period.<sup>37,38</sup> This makes it difficult to time a definitive procedure that may be required. Deferring noncritical injuries and nonurgent soft tissue reconstructive procedures by even a few weeks may create a new set of problems. We should, therefore, be mindful about what we label as nonessential. These definitions should constantly be re-evaluated, taking into account current conditions and existing resources, both of which may evolve through time. We are in a situation in which we must rationalize resources, save life over limb, and achieve the maximum utility for the largest number of patients. At the same time, we must keep ourselves healthy. We also have to make sure our patients do not feel abandoned at their time of greatest need. In addition, we need to maintain team morale, prevent burnout, and ensure our residents get trained. We will then have to prepare for the next wave of patients that may have not had their needs met during the pandemic.

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