



EMERGENCY HAND & RECONSTRUCTIVE MICROSURGERY IN THE COVID-19 POSITIVE PATIENT

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PII: S0363-5023(20)30410-X

DOI: <https://doi.org/10.1016/j.jhsa.2020.07.013>

Reference: YJHSU 56121

To appear in: *Journal of Hand Surgery*

Received Date: 4 May 2020

Revised Date: 25 June 2020

Accepted Date: 27 July 2020

Please cite this article as: De SD, Chang Liang Z, Eu-Jin Cheah A, Puhaindran ME, Lee EY, Tang Lim AY, Sze Chong AK, EMERGENCY HAND & RECONSTRUCTIVE MICROSURGERY IN THE COVID-19 POSITIVE PATIENT, *Journal of Hand Surgery* (2020), doi: <https://doi.org/10.1016/j.jhsa.2020.07.013>.

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DECLARATIONS

1. **Conflicting interests:** The authors have no conflicts of interest to declare.
2. **Ethical review committee statement:** Institutional ethical committee review was not

necessary for this report.

3. **Funding:** The authors did not receive any funding.

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Abstract

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, non-specific 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 peri-operative care of the COVID-19 positive patient have been published. However, our practices differ from general orthopedic and plastic surgery, primarily because of the focus on trauma. This article discusses the peri-operative and technical considerations that are essential to manage the COVID-19 patient requiring emergency care, without compromising clinical outcomes and while ensuring safety of the attending staff.

26

27 COVID-19 has disrupted all aspects of routine life, with the healthcare industry at the
28 forefront of this raging pandemic^{1,2}. Many centers around the world have cancelled elective
29 and non-urgent orthopedic and plastic surgical procedures to protect healthcare workers and
30 patients, as well as to conserve hospital resources. However, in many places, surgeons
31 continue to see a steady stream of limb-threatening cases that require emergent surgical care,
32 mainly because some key industries (e.g. construction; oil and gas) continue to function. It is
33 neither practical nor ethical to defer such cases. With the increase in community-spread, an
34 increasing number of infected patients may be asymptomatic³ or have mild, non-specific or
35 atypical symptoms⁴. Some of them may already have an ongoing, severe infection. The time-
36 sensitive nature of some of these cases means that hand surgeons may need to operate
37 urgently on patients who are suspected of COVID-19 infections, often before confirmatory
38 test results are available. General guidelines for the peri-operative care of COVID-19 positive
39 patients have been published⁵. However, hand surgeons face additional challenges, primarily
40 because of our focus on trauma. This article outlines some specific peri-operative and
41 technical considerations in the management of COVID-positive patients with urgent, limb-
42 threatening conditions that seek to avoid compromising clinical outcomes while ensuring
43 safety of the attending medical staff.

44

45 ***Patient demographics and risks factors***

46 The main hand and upper limb conditions that require immediate surgical care are severe
47 open injuries, infections and less commonly, bleeding / fungating tumors. Open fractures,
48 tendon injuries and ligament injuries also need to be addressed early. Infections tend to occur
49 in the elderly with compromised immunity (e.g. diabetes, chronic steroid treatment),
50 comorbid illnesses (e.g. renal impairment) and decreased physiologic reserves (e.g. heart

disease). There is evidence that the elderly with pre-existing conditions have the highest risk of mortality from COVID-19^{6,7}. 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-19⁸, but there are two 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 (ALI) secondary to COVID infection, possibly due to an over-active immune response⁹. 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 communities¹⁰. 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.

Pre-operative considerations and planning

The principles of surgery in a COVID-positive patient is akin to war-time surgery, where surgical triage, thorough rationalization of resources and time-efficiency are crucial⁵. The overarching principles in managing COVID-positive patients are: (1) ensure 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 (e.g. major limb replantations) place the highest demand on the patient and the medical team. A multi-disciplinary 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 if 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 reexamine our manpower distribution and routine workflows. We have re-organized our department into two 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 (OR). 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 (SR) 1 in team A takes call on Monday and Friday while SR 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 where 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 one 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 intra-operative decision-making and take breaks during long procedures. As much as possible, however, we advocate minimizing the number of medical

staff in the OR and the most senior surgeon must be in attendance for difficult cases⁵. 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 “non-essential” work, tailored to the severity of the COVID-19 situation locally. In the earlier phases, we cancelled elective, complex surgery requiring inpatient hospitalization (e.g. brachial plexus reconstruction) and continued with ambulatory cases under local anesthesia (LA). 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 OR protocols for COVID-19 positive patients have been described in detail⁵. 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^{5,11–13}. In addition, a powered air-purifying respirator (PAPR) should be used when an aerosol-generating procedure, such as drilling/sawing is anticipated^{5,14}. This is reasonable for short procedures but is extremely taxing for operations that extend beyond 3-4 hours. It is also impossible to use the operating microscope with a full PAPR setup. We use high-magnification loupes (3.5 to 4x) with PAPR suits for procedures involving medium-sized vessels (e.g. radial artery repair). For procedures mandating the operating microscope (e.g. digital artery repairs), the surgeon will have to remove the PAPR and wear goggles or a face shield instead. It is important that all parts of the surgery that potentially generate aerosols should be completed before transitioning to the operating microscope (**Figure 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 non-critical 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 dilemma¹⁵. 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 OR resources are not taxed.

Anesthesia

The current guideline for anesthesia in COVID-positive patients is to minimize aerosolization^{14,16}. 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)^{17,18}. This minimizes the risk of COVID-19 aerosolization from intubation. We have adapted some aspects of the WALANT (Wide Awake, Local Anesthesia, No Tourniquet) technique¹⁹ 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 pandemic²⁰.

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 where the outcomes are expected to be favorable. However, the risks in a COVID-positive 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 trans-metacarpal 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 post-operative pain relief²¹ and peripheral vasodilation (for microvascular procedures)²². 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 one or two K-wires. This was originally described to prevent entangling adjacent blood vessels during pinning²³ but, in this context is a method to minimize aerosolization. For larger bones (e.g. 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 where there is a wide zone of injury and the vessels are of uncertain quality. Finally, the surgeon must also determine if 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 de-isolated. In extenuating circumstances, banking of amputated parts (e.g. ectopic banking; cryopreservation) and delayed replantation may be considered, although we have limited experience with this²⁴⁻²⁶.

Infections

Severe, spreading infections such as necrotizing fasciitis should be treated as surgical emergencies and the patient must be brought to the OR as soon as possible. Other infections such as paronychia, deep space abscesses and flexor tenosynovitis should ideally be addressed within 4-6 hours. We use local anesthesia (e.g. 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 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 identified risk factors predicting persistence of infection and the need for repeated debridements^{27,28}. There are similar criteria for specific infections such as flexor tenosynovitis²⁹ and necrotizing fasciitis^{30,31}. These criteria enable hand surgeons to identify patients with 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 OR resources are limited, we drain localized infections (e.g. paronychia) in the ward or an ambulatory facility. Hyatt et al 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 available³². Definitive soft tissue reconstruction should be deferred, and interim negative pressure dressings may help post-operative wound care and nursing requirements.

Open fractures, tendon, nerve and ligament injuries

Open wounds with underlying non-critical injuries (e.g. nerve, tendon, bone) should be thoroughly cleaned under an appropriate block and sterile dressings applied. These

procedures may be performed in the emergency room (ER) and further tests to ascertain the patient's COVID status should be obtained⁵. 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 under local or regional anesthesia. All other closed injuries (e.g. distal radius fractures) should be reduced and treated in a thermoplastic / plaster splint while the patient recovers. An exception to this is when severely displaced fractures cause impending skin, neurologic 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 compliance³³. 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 (e.g. 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 where urgent soft tissue reconstruction is necessary (e.g. 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 defects³⁴. Finally, emergency free flaps should only very rarely be necessary to provide concomitant soft tissue coverage and revascularization.

POST-OPERATIVE CONSIDERATIONS

Any COVID-positive patient who has undergone a major procedure should be nursed in a high-dependency unit or ICU⁵. However, the nursing staff may not be familiar with some of the specialized requirements (e.g. 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 nursing team. 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 (e.g. 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.

There are several pharmacological issues that 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 (e.g. 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 (DVT) must be carefully balanced with the risks of bleeding and sub-flap hematoma that may compromise the circulation. There is increasing evidence that COVID-19 may induce a hypercoagulable state³⁵ and Schultz and Wolf reported on two COVID-19 patients with digital ischemia³⁶. This is likely multifactorial due to thrombo-inflammation, embolism, use of inotropes and a vascular “steal” phenomenon in patients on extra-corporeal membrane oxygenation (ECMO). Digital ischemia portends an overall poorer prognosis and could also adversely affect recovery of the primary hand condition. The authors suggested a multi-modality approach including judicious use of anti-coagulants, warming, topical nitroglycerin and close observation³⁶. 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 healthcare 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 if there will be a second wave. Worse still, some infected patients may even be re-infected and display a persistent “positive” status

for a prolonged period^{37,38}. This makes it difficult to time a definitive procedure that may be required. Deferring non-critical injuries and non-urgent 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 non-essential. 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 where 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.

FIGURE LEGENDS

Figure 1 (A-C)

(A): A 26-year-old male manual worker 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 ER.

(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 OR 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 post-operatively until the swab results were known. He tested negative for COVID and was subsequently discharged from inpatient care 5 days later.

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