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CONCEPTS

Infectious Disease

Integration of aeromedicine in the response to the COVID-19 pandemic

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Abstract

There is limited guidance on the use of helicopter medical personnel to facilitate care of critically ill COVID-19 patients. This manuscript describes the emergence of this novel virus, its mode of transmission, and the potential impacts on patient care in the unique environment of rotor wing aircraft. It details the development of clinical and operational guidelines for flight crew members. This allows other out-of-hospital clinicians to utilize our framework to augment or supplement their own for the current response effort to COVID-19. It further serves as a road map for future response to the care of high consequence infectious disease patients.

KEYWORDS
aeromedicine, COVID-19, decontamination, ECMO, EMS, HCID, helicopter air ambulance, infectious disease, PPE, prehospital medicine, SARS-CoV-2, STEMI

1 | INTRODUCTION

In late December 2019, the novel SARS-CoV-2 virus was identified in Wuhan, China. The resulting disease, now universally known as Corona Virus Disease 2019 (COVID-19), was declared a public health emergency of international concern by the World Health Organization on January 30, 2020.[1] A Presidential declaration of national emergency followed on March 13, 2020.[2] The virus, which is a ribonucleic acid

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virus of mammalian origin, is spread via respiratory droplets in a manner similar to what was experienced in the severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS). SARS-CoV-2 is highly infectious and can cause a severe pulmonary illness with features similar to acute respiratory distress syndrome.[3] The most common symptoms seen early in the spread of this virus in Wuhan, China, were fever, cough, and shortness of breath, with higher mortality rates seen in patients older than 60 years and in those with common medical comorbidities like diabetes, hypertension, and coronary artery disease.[3] Though COVID-19 resembles SARS and MERS, the case fatality rate appears to be significantly lower.[4] Furthermore, limited data from the SARS infection in 2003 suggested that emergency medical service (EMS) providers might be at a higher risk of contracting this high consequence infectious disease (HCID) than the general population.[5] Due to the rapidly evolving nature of the pandemic, the development of aeromedical transport guidelines that were safe and effective at preventing transmission of the virus during clinical resuscitation became paramount.

Memorial Hermann Life Flight services an area in Houston, TX, of ≈150 miles and a population of over 4 million, completing >3,000 missions annually. Following the first patient identified with COVID-19 in Houston on March 1, 2020, the clinical administrative staff at Memorial Hermann's Life Flight air ambulance service was tasked with establishing a guideline for the transport and management of COVID-19 patients.[6]

2 | UNIQUE ENVIRONMENTS OF EMS AND AEROMEDICINE

Ground EMS ambulances are uniquely equipped to manage droplet and airborne diseases. They do so often in caring for patients with influenza (droplet transmission) and tuberculosis (airborne transmission). Isolation of the patient compartment from the passenger compartment and filtration of the air are possible in ground transport vehicles, which creates a safer environment for the healthcare workers who work within them.

In contrast, a helicopter air ambulance is unable to isolate the pilot compartment from the patient compartment – the cabin is typically a single, shared environment between the pilot and medical personnel.[7] This presents a unique challenge: protection of both the pilot and the medical flight crew. Helicopter utilization in the transport of HCIDs is further complicated by the size of the aircraft, as it is uniformly accepted that patient placement should be away from the pilot whenever possible, which makes this guideline more feasible for larger air frames in which the patient compartment is in the aft.[8] Of course, certain fixed wing aircraft could be considered, as fixed wing commercial aircraft have the unique ability to limit the recirculation of air.[8] However, only a minority of aeromedical agencies in the U.S. utilize fixed-wing aircraft for patient care, typically for long-distance transports.

2.1 | Current literature on the use of rotor wing aircraft in response to HCID

The initial step in developing rotor wing aircraft clinical and operational guidelines in response to COVID-19 was a literature review regarding this topic. A search of PubMed using the MeSH terms ("Communicable Diseases"[Mesh]) AND "Air Ambulances"[Mesh] returned only 4 results. PubMed returned no results for a search using the terms ("COVID-19" [Supplementary Concept]) AND "Air Ambulances"[Mesh]. The terms ("Air Ambulances"[Mesh]) AND infectious disease returned 13 articles, of which only five were relevant. Combinations of related terms were used to ensure exhaustive search results.

Current CDC guidance for helicopter air ambulance involvement in COVID-19 patient care is based largely on case reports and case series that were published following the SARS and MERS epidemics, as well as in response to Lassa fever in the 1970s.[9] More recently, clinical guidelines have been developed for the safe transport of patients with Ebola virus disease in portable isolation units utilizing both ground ambulances, as well as rotor wing aircraft and large military cargo planes.[9,10,11] Additionally, there is little recent data on uniform domestic policies or clinical guidelines among helicopter air ambulance agencies when it pertains to the management of HCID patients.[12,13] The last broad survey in the U.S. was administered in 1996. At that time, there was little uniformity in the approach to the care of such patients or standardized clinical guidelines amongst the aeromedical services. In fact, the most common reported reason for flight refusal for HCIDs was tuberculosis.[14]

In response to the current COVID-19 pandemic, the involvement of helicopters and flight medical teams has been sporadic. In the midst of rapid expansion of this virus in Italy, the Italian military helicopters (HH-101A) were integrated into their national plan on March 6, 2020. These particular aircraft are typically utilized for specialized transports and are staffed by crews who have extensive biocontainment training.[15] In the United States, both fixed wing and rotor wing aircraft are being utilized in response to COVID-19. However, the response lacks uniformity, and there remains uncertainty about the safety of flight crews in close proximity to these HCID patients.

3 | DEVELOPMENT OF ROTOR WING CLINICAL AND OPERATION GUIDELINES FOR HIGH CONSEQUENCE INFECTIOUS DISEASE PATIENTS

Identification and inclusion of key stakeholders was the next critical step in development of these guidelines. The following individuals were identified as vital in the development of a successful strategy to incorporate the helicopter air ambulance program into the system response to COVID-19: flight program director, medical director, chief flight nurse, chief pilot, safety officer, chief of dispatch, chief of helicopter maintenance, the disaster management physician for the hospital system, the lead physician for infectious diseases for the hospital system, emergency department (ED) clinical leadership, hospital leadership, and specialty program clinical leadership in both extracorporeal membrane oxygenation (ECMO) and pediatric critical care. This team of specialists was identified and met frequently over the course of a 2-week span. The goal was to develop a practical guideline for the safe transport of HCID patients while protecting the flight crew and maintaining their safety. A working document for the clinical and operational care of COVID-19 patients was created and distributed to personnel for final approval. Flight crew buy-in was felt to be critical in the success of establishing such a protocol. Out-of-hospital providers have been shown to be more comfortable in caring for patients with HCIDs (as seen in the response to the Ebola Virus) when they are provided adequate training on the procedures and transparency from hospital and organizational administration.[16]

Challenges Identified in the Creation of the COVID-19 Rotor Wing Guidelines:

Early in the process of development of these guidelines, several key areas of focus were identified: (1) dispatch, (2) personal protective equipment (PPE), (3) medical crew arrangement & patient care, (4) aviation operations, and (5) decontamination.

3.1 | Dispatch

CDC guidance for public-safety answering points and emergency medical dispatch centers includes recommendations that dispatchers should modify caller screening questions to include COVID-19 questions and notify EMS clinicians as early as possible prior to patient contact.[7] This was implemented with our dispatch team and flight crews for all calls, including scene flights. Although this guideline was intended to focus on interfacility transports for known COVID-19 positive patients and patients under investigation (PUIs), it was recognized that some PUI and COVID-19 patients may not self-identify in this manner. The following list of screening questions was utilized to help identify HCID patients:

1. Does the patient have a temperature ≥100.1?
2. Does the patient have new onset of coughing?
3. Does the patient have nasal congestion unrelated to allergies?
4. Does the patient have a sore throat?
5. Does the patient have shortness of breath unrelated to chronic disease?
6. Does the patient have new onset of diarrhea?
7. Is the patient living with someone who is under mandated 14-day quarantine for COVID-19 exposure?
8. Does the patient have a known contact with someone with COVID-19?

If any answers to the above questions were yes, guidance was given to contact the Chief Flight Nurse in order to dispatch the designated COVID-19 crew.

Dispatch plays a critical role in screening and prioritizing the incoming interfacility transfer requests for COVID-19 patients, and those identified as PUIs (persons under investigation). Each request for transport of a COVID-19 or PUI patient is first screened by dispatch, then discussed with the Chief Flight Nurse and Medical Director for both safety and appropriateness. Prioritization is given to higher acuity patients requiring ventilatory support, vasopressor support, and ECMO. The flight medical crew is provided an opportunity to review the patient chart from the sending facility, when available, and to have a phone conversation with the sending medical providers. This process is unique to the COVID-19 response aircraft. Prior to implementation of the COVID-19 clinical and operational guidelines, medical crew members were blinded to their dispatched calls. Typically, they would not receive report from the requesting facility regarding patient details until they are in flight. However, dispatch and the clinical administration felt it was necessary to the mission of the COVID-19 aircraft to receive detailed report prior to launch. This allows the medical crew members the ability to prepare the aircraft, pre-plan their equipment, and safely execute the mission. As crew safety remains the primary concern for any mission, the pilot is afforded the opportunity to accept or reject the mission based on weather conditions prior to the unblinding of the medical crew.

Dispatch also plays an integral role in communicating with the receiving facility and in coordinating essential hospital personnel and equipment. This allows the receiving medical team adequate time to don personal protective equipment (PPE) and prepare the isolation room for the incoming COVID-19 patient, as well as prepare the necessary equipment and personnel to expedite the patient hand off safely and allow the flight crew to begin the tedious, but essential decontamination procedures.

3.2 | PPE for medical crew

Heightened awareness of air medical crews is critical to preventing further spread of the virus to themselves and to future patients involved in helicopter transport in the same aircraft.[17] Strict adherence and training on appropriate PPE guidelines and decontamination procedures are the mainstay for prevention of further transmission in prehospital workers when managing HCIDs.[18,19] The unique working environment of the helicopter cabin is an enclosed space in which rapid patient assessment and clinical resuscitation must be performed. This creates the potential for aerosolizing procedures.[7] Due to the restrictions of this environment, the Food and Drug Administration recommends N95 masks when available, as well as gowns and gloves. These recommendations are consistent with the current CDC guidelines.[7]

The following PPE arrangement for care of COVID-19 patients was selected: N-95 respirator, eye protection, face shield, impermeable gown, and gloves. Surgical facemasks are placed on all patients irrespective of COVID-19 diagnosis or the reason for transport due to the high prevalence of the disease in the community and the unclear rate of atypical or asymptomatic infection.[13] Helmets were replaced by headsets for the medical crews as this particular PPE arrangement did not allow for appropriate helmet placement.

3.3 | Medical crew arrangement and patient care

Life Flight employs a flight nurse, flight paramedic, and pilot staffing model. Additional clinical crewmembers are typically included for specialized patient care (eg, pediatric critical care and ECMO). However, this specialized staffing model was updated on the COVID-19 aircraft (discussed in detail below). The ride-along program was halted in response to regional and state guidance to limit contact with COVID-19 patients by non-essential personnel. While the pediatric critical care transport team would continue to transport non-COVID-19 patients in the aircraft, adult medical crews were assigned to transport pediatric COVID-19 and PUI patients. An exception to the staffing restrictions was made for perfusionists in the event of a COVID-19 ECMO transport.

Revisions to existing patient care protocols, specifically regarding airway management, were necessary to limit the number of clinical providers involved in invasive airway maneuvers, as this had been shown to be associated with increased risk of transmission of HCIDs to healthcare workers during the SARS epidemic.[20] The following airway management guideline was implemented for the COVID-19 aircraft and flight crew:

1. Early endotracheal intubation (ETI) at sending facility for patients requiring high flow nasal cannula or noninvasive positive-pressure ventilation (NIPPV)
2. Avoidance of nebulized therapies in the aircraft[4,20]
3. Avoidance of high flow nasal cannula and NIPPV in the aircraft[4]
4. Adequate preoxygenation strategies and apneic oxygenation during ETI
5. Rapid sequence intubation with high-dose neuromuscular blocking agents[4]
6. Avoidance of manual bag valve mask technique and suctioning, when possible
7. Emphasis on first-pass success, utilizing bougie and video laryngoscopy[4]
8. Limiting ventilator disconnects and clamping the endotracheal tube at end expiration when transferring patient care
9. Emphasis on use of closed-circuit ventilation strategies with viral filters at both the compressor inlet and the exhalation valves[13]

*It is important to note that prior to development of this COVID-19 airway guideline, our standard patient care guidelines emphasized adequate preoxygenation and utilization of bougie and video laryngoscopy with all intubations.

Though the topic of early endotracheal intubation of COVID-19 patients is highly debated, the environment of the aircraft is better suited for HCID patients on closed circuit ventilatory support. As mentioned previously, turbulence in the aircraft as well as the limited space increases the risk of exposure to flight crews when patients require potentially aerosol-generating procedures (ie, nebulizer therapy, suctioning, high flow nasal cannula, CPAP, BiPAP, etc).[7] Though our guidelines did not mandate intubation of every COVID-19 patient, recommendation was given for patients to be intubated at the sending facility prior to flight if they had the potential for respiratory failure in flight or requirement of the above-mentioned procedures.

Adjustments were also made to the approach in caring for cardiac patients in flight. Our standard guidelines for ST segment elevation myocardial infarction (STEMI) patients utilize tenecteplase administered in-flight for systemic thrombolysis, typically followed by immediate transport to the catheterization suite upon arrival at the facility. However, due to the heightened concern for STEMI patients presenting with concomitant COVID-19, the operational guidelines were updated to include transport of these patients to the emergency department for COVID-19 screening and potential rapid testing prior to decision to go to the cardiac catheterization suite.

3.4 | Aviation operations

Unique to air ambulances, the crew consists of personnel (pilots) that are assigned solely to the operation of the aircraft. The addition of a pilot creates further opportunity to improve operational guidelines in response to HCIDs. Multiple challenges were identified that were specifically related to the pilot and the aircraft operations.

3.4.1 | Designation of the COVID-19 aircraft and flight crew

A single EC-145 aircraft of our 5-base, 6-helicopter fleet was designated as the COVID-19 aircraft. The aircraft chosen was the one assigned to central base, housed atop the level 1 trauma center. Typically, this aircraft is staffed twelve hours daily to perform specialty flights (ECMO, balloon pump, LVAD, Impella, neonate/pediatric, obstetrics, etc). However, with the expected increase in COVID-19 flights, this aircraft was assigned to cover these patients 24 hours a day, 7 days a week in order to limit the number of aircraft that would need downtime for decontamination and to limit the number of crewmembers exposed to this virus. Crew members were selected on a volunteer basis. The COVID-19 aircraft became operational on April 1, 2020.

3.4.2 | PPE for pilots

As our rotor wing aircraft have an open compartment between the patient care area and the cockpit, pilots were fitted with N-95 respirators to provide appropriate personal protection in the event that a patient in transport required aerosolizing procedures.[7] These are worn with their standard flight suit and helmet uniform. The aircraft was stocked with emergency PPE kits to allow the pilots to don further protection (gown and gloves) if necessary. In order to decrease the potential for breach in PPE and exposure to COVID-19, pilots were restricted from assisting with patient loading and off-loading, unless absolutely necessary (due to patient weight, accessory equipment, stretcher failure, etc). This restriction was designed to prevent contamination of the instrument panels and flight controls. All COVID-19 missions require the blackout curtains to be drawn to add a final layer of protection for the pilot and cockpit.

3.4.3 | Flight restrictions with COVID-19 patients

Despite our fleet and crew members having the capability to utilize instrument flight rules and night vision goggles, certain restrictions were imposed with the COVID-19 aircraft. In order to minimize the potential for aborted missions due to weather and unexpected turbulence in flight, it was determined that the COVID-19 patients would be flown solely under visual flight rules (VFR). As part of this operational guideline, VFR minimums were increased to the following, utilizing the standard flight measurement value of statute miles (SM):

	Local	Cross-Country
DAY	1000’ 3 SM	1000’ 5 SM
NIGHT	1000’ 5 SM	1500’ 5 SM

3.4.4 | Fueling restrictions and landing zone issues

Due to the sensitive nature of these interfacility transports, once patient-loaded, refueling was restricted until after completion of the mission and decontamination of the aircraft. The purpose of the fueling modifications was 2-fold: (1) reducing contact with the general public, and (2) generating a quicker turn-around time at our personal fueling locations. This is important in returning the aircraft to service after a lengthy decontamination process. Hot-loading and offloading were also removed from operational guidelines on the COVID-19 aircraft. Finally, an unexpected barrier to patient care and transport was discovered during the early phases of hospital response to the pandemic in Houston. Many community hospitals were erecting triage field tents in their parking lots. This created a potential hazard for the pilot, as many of these were being placed in the vicinity of the designated helipads. This required detailed reconnaissance of our Houston area helipads and open lines of communication with flight crew on approach to these facilities, to prevent safety mishaps.

3.5 | Decontamination procedures

Medical helicopters, like ground ambulances, can be difficult to decontaminate.[21] The decontamination procedure consists of 3 main steps:

1. Air out of the aircraft with exits and doors open for 30 minutes[13]
2. Spray and wipe down of all surfaces with a 1:10 bleach solution and a virucidal disinfectant solution, allowing for time to dry
3. Terminal clean with ultraviolet (UV) light exposure

Though utilization of UV light as a terminal cleaning procedure involving rotor wing aircraft is uncommon, there is promising literature involving UV light utilization in ambulances, radiology suites, and operating rooms.[22,23] This step of the decontamination process was necessary to provide additional protection for our flight crews and for subsequent patients. Maintenance personnel were also trained in appropriate donning and doffing procedures to allow for assistance with decontamination of the aircraft as well as routine and unscheduled maintenance.

3.6 | Successful implementation of the Covid-19 guidelines

On April 2, 2020, we completed our first COVID-19-positive patient transport. At the time of dispatch for this mission, the patient was being cared for in the intensive care unit of a community hospital. The patient had profound hypoxemia and shock requiring ventilatory and vasopressor support as well as prone positioning. The flight team, in conjunction with the perfusion team, assisted with cannulation for ECMO and then transported the patient to the quaternary care center for admission to the designated COVID-19 Intensive Care Unit. There were no reported PPE breaches and the crew has since completed their 14-day self-monitoring program that involves fever and symptom analysis twice daily. To date, we have successfully cared for 6 COVID-19 patients, all of whom required invasive ventilatory support. In total, 8 flight crew members have been involved in HCID transports, and none have warranted testing or quarantine based on symptoms and exposure risk per CDC guidance.[24]

4 | CONCLUSION

At the time of writing this manuscript, all 50 states have reported cases of the virus. ≈1,062,446 COVID-19 cases have been reported nationally with 62,406 fatalities (816 in Texas).[25,26] In developing these guidelines, the CDC guidance from the SARS response was utilized heavily, as was feedback from our colleagues in the aeromedical community. Early identification of potential hurdles and the importance of integrating hospital leadership and subspecialty partners were critical to the completion of these guidelines.[27] Flexibility and maintaining a working document are important, as this pandemic will continue to produce clinical data that will further influence the care of this unique patient population and improve aeromedical response and integration into future medical disasters.

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