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## Air Medical Journal

journal homepage: <http://www.airmedicaljournal.com/>

## Feature Article

## Mass Air Medical Repatriation of Coronavirus Disease 2019 Patients

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## A B S T R A C T

Recent coronavirus disease 2019 (COVID-19) events have presented challenges to health care systems worldwide. Air medical movement of individuals with potential infectious disease poses unique challenges and threats to crews and receiving personnel. The US Department of Health and Human Services air medical evacuation teams of the National Disaster Medical System directly supported 39 flights, moving over 2,000 individuals. Infection control precautions focused on source and engineering controls, personal protective equipment, safe work practices to limit contamination, and containment of the area of potential contamination. Source control to limit transmission distance was used by requiring all passengers to wear masks (surgical masks for persons under investigation and N95 for known positives). Engineering controls used plastic sheeting to segregate and treat patients who developed symptoms while airborne. Crews used Tyvek (Dupont Richmond, VA) suits with booties and a hood, a double layer of gloves, and either a powered air-purifying respirator or an N95 mask with a face shield. For those outside the 6-ft range, an N95 mask and gloves were worn. Safe work practices were used, which included mandatory aircraft surface decontamination, airflow exchanges, and designated lavatories. Although most patients transported were stable, to the best of our knowledge, this represents the largest repatriation of potentially contagious patients in history without infection of any transporting US Department of Health and Human Services air medical evacuation crews.

Published by Elsevier Inc. on behalf of Air Medical Journal Associates.

Recent coronavirus disease 2019 (COVID-19) events have presented novel challenges to health care systems worldwide. Air medical movement of individuals at elevated risk of highly infectious disease poses unique challenges and threats to crews and receiving

medical personnel. These individuals may have tested positive or were under investigation for this highly infectious disease. The first case of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was identified in Wuhan, China, in late 2019, the epicenter of the COVID-19 outbreak. The virus quickly spread across China and the globe,<sup>1</sup> until the World Health Organization declared COVID-19 a pandemic on March 11, 2020.

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Before COVID-19 was known to spread throughout the United States, a significant number of US citizens and diplomats were evacuated from Wuhan, China. Phoenix Air (Carterville, GA) contracted by the US Department of State (DoS) with medical monitoring performed by accompanying DoS medical providers conducted international flights. The US Department of Health and Human Services (HHS) provided medical monitoring and care during subsequent domestic flights around the country. HHS air medical evacuation teams (AETs) of the National Disaster Medical System (NDMS) directly supported 39 flights, moving over 2,000 individuals, all of whom were either COVID-19 positive, persons under investigation (PUIs), or individuals who were asymptomatic.

### The Emergence of COVID-19

Coronavirus is a large family of viruses with a variety of hosts. Some types of coronavirus circulate in humans and result in mild illness such as the common cold. Other members of the coronavirus family have zoonotic origins and cause severe illness when contracted by humans. Examples of zoonotic coronavirus types causing severe illness in humans are severe acute respiratory syndrome-associated coronavirus (SARS-CoV) transmitted from civet cats, and Middle East respiratory syndrome coronavirus (MERS-CoV) transmitted from dromedary camels. There are several other strains of coronavirus known in animals that have not yet been reported to have infected any humans. COVID-19 is spread from person to person through droplets,<sup>2</sup> and there are indications it may also be airborne.<sup>3,4</sup>

The current world outbreak of COVID-19 is caused by a new coronavirus that emerged in 2019 called SARS-CoV-2.<sup>5</sup> Although patient zero has not been determined, 9 cases of COVID-19 are now suspected of having come to medical attention in Wuhan, China, in November 2019. The number of cases increased rapidly, reaching 27 suspected cases by December 15 and 60 by December 20, 2019.<sup>6</sup> Current estimates are the number of infected persons worldwide doubles every 2 to 3 days.<sup>7</sup> As of March 25, 2020, there were 438,749 confirmed cases and 19,675 confirmed deaths due to COVID-19 throughout the world. COVID-19 has been reported in 172 countries as of March 25, 2020. At the time, the overall death rate in the world was 4.48% but ranged from 9.85% in Italy to 0.51% in Germany and 1.23% in the United States.

### Background

#### *Emerging Global Infectious Diseases*

Since the 1970s, approximately 40 emerging infectious diseases have been identified including SARS, MERS, Ebola, Zika, Avian influenza, and Swine influenza. With increased travel on a global and regional scale and urban expansion, there is significant potential for the rapid spread of emerging infectious diseases and pandemics. Another possibility is the deliberate introduction of diseases into human, animal, or plant populations as part of a terrorism act. Known weaponized agents include anthrax, smallpox, and tularemia.

Multiple factors lead to the emergence or reemergence of infectious diseases. Some are natural processes, and others are the result of human behavior. These factors also contribute to the rapid worldwide transmission of these diseases. In fact, the close proximity of gatherings in addition to environmental factors during air and sea travel appear to hasten the spread of respiratory viruses such as SARS-CoV-2. The limited available space on both ships and airplanes not only creates confined spaces for airborne droplet transmission but also provides abundant fomites for disease transmission because of large groups of people sharing common areas, such as dining areas and restrooms. Door handles, serving utensils, and other objects are repeatedly handled, and hand hygiene may not be consistently

performed. Cruise ships appear to be an extremely high-risk environment for virus transmission.

#### *Response Preparedness*

In 1984, the NDMS was formed as part of the Public Health Service in HHS as a partnership between the Federal Emergency Management Agency, the DoD, and the Department of Veterans Affairs. The purpose of the NDMS was to provide medical evacuation and definitive care of evacuated military and civilian casualties from overseas war contingencies, with a secondary mission to supplement state and local medical resources during disasters and emergencies.<sup>8</sup> In 2003, after 9/11, the convening authority over the NDMS was granted to the Federal Emergency Management Agency within the Department of Homeland Security. After Hurricane Katrina, the NDMS was reorganized under the HHS as legislated by an Act of Congress to provide administrative and operational control as outlined in the Public Health Service Act of 2006 and amended by the Pandemic and All-Hazards Preparedness Act of 2006 and the Pandemic and All-Hazards Preparedness Reauthorization Act Preparedness and Advancing Innovation Act of 2019.<sup>9</sup>

Forward thinking, in conjunction with an increased tempo of military operations, resulted in a diverse focus that included the need to assist with air medical staging and broader humanitarian efforts. This initially led to the development of the mobile acute care strike team, which was intended to serve as a critical care resuscitation and stabilization unit to hold patients awaiting departure from a disaster air medical staging facility (DASF). Patients would arrive from their point of injury/illness to the DASF to await DoD flights to definitive care. The DASF is often collocated with a US Air Force medical group, which provides care to less acute patients and serves as a liaison for military air transport. During a busy hurricane season in 2017, the need for nonmilitary critical care air transport was identified, and the concept behind the HHS AET was born. The HHS AE Team is composed of active critical care and air transport providers who have received training through 2 pathways: the US Air Force School of Aerospace Medicine Critical Care Air Transport program (2-4 weeks) or the HHS partnership with Florida International University air medical evacuation course (1-2 weeks). After training, these providers have participated in ongoing validation with multiple air medical transport teams nationwide.

#### *Past Repatriation/Air Medical Transport of Patients With Infectious Diseases*

In the late 1970s, the US Army Medical Response Institute of Infectious Diseases created the air Aeromedical Isolation Team. It was designed to safely care for and evacuate contagious patients in high-level containment conditions. It was primarily intended for bioterrorism response and extraction of scientists or health care workers with infections in foreign countries. Early missions focused on hemorrhagic fevers, and although it was deployed only 4 times, the team also was used in an advisory capacity for respiratory illnesses to include SARS and multidrug-resistant tuberculosis.

A cooperative development effort between the US government and the World Health Organization resulted in Phoenix Air developing the Airborne Biological Containment System. This single-patient, negative-pressure isolation unit was designed for use on their Gulfstream III aircraft. During the 2014 Ebola outbreak, this system was used to transport 41 patients to medical facilities in the United States and Europe. The need for increased capability led to the development of the Containerized Bio-Containment System, which is able to transport 4 infectious patients in an intensive care unit environment. In conjunction with the DoS contract, the Containerized Biological Containment System was used on overseas repatriation missions inside a Boeing 747-400 aircraft, which was reconfigured for mixed passenger/cargo work (Fig. 1).



**Figure 1.** Containerized Bio-Containment System.

Because of the complex setting of air medical evacuation for a highly contagious infectious disease, especially found in repatriation missions that often involve long distances, patients must be optimized before transport. Only patients likely to survive transport will be evacuated. Especially in the case of pulmonary insult, which is predominant in SARS, patients requiring extracorporeal membrane oxygenation may need to complete therapy before air medical evacuation. The physiologic effects of flight and confinement can be difficult for healthy patients, much less those with extensive pathology. Dependent on the specific platform used for the mission, mechanical ventilation may not be possible, further necessitating stabilization before transport. Additionally, patients with hemodynamic instability, severe anemia, and conditions that may be aggravated at altitude (eg, a pneumothorax, bowel obstruction, and pneumocephalus) should be treated before transport.

#### *Evacuation of American Citizens in China*

On January 29, 2020, a chartered Boeing 747 transported the first American citizens and their immediate family from Wuhan, China, to March Air Force Base, Riverside County, CA.<sup>10</sup> In early February, 4 additional flights transported the remainder to several other military sites. A total of approximately 800 passengers were repatriated via charter flights from Wuhan to the United States. These flights represented a joint effort between the DoS, HHS, and the Centers for Disease Control and Prevention (CDC). In-flight medical monitoring was provided by DoS medical teams supplemented by an infectious disease specialist from Wuhan to US military bases in California. Two of those flights continued from Travis Air Force Base, CA; Miramar Marine Corps Air Station, San Diego, CA; Lackland Air Force Base, TX; and Camp Ashland, NE, carrying several hundred of the Wuhan evacuees with HHS AETs on board to provide medical monitoring and support. At those military bases, the evacuees were screened for signs and symptoms of COVID-19 and placed into medical facilities or quarantine.

#### *Diamond Princess and Grand Princess Cruise Ships*

Cruise ships have long been recognized as a potential hotbed during infectious events. In the past, they were primarily associated with gastrointestinal disturbances such as norovirus. COVID-19 demonstrated the ease of transmission and highlighted additional areas of concern with the general demographic found on cruise ships. The average age of passengers is 46.9 years, with a median age between 60 and 69 years.<sup>11</sup> This increased age is associated

with multiple comorbidities that have proven to be a hallmark of COVID-19 mortality.<sup>12</sup> Early outbreaks on the Diamond Princess and the Grand Princess delivered a grim reality—the close quarters of the cruise ship environment allowed COVID-19 to spread almost unchecked, quickly increasing among crew and passengers. Recognizing the inherent danger to passengers and threat to public health during this epidemic, Cruise Lines International Association, the world's largest cruise industry trade association, announced on March 13, 2020, that it was following CDC guidance and temporarily suspending ocean-going cruise operations from US ports of call for 30 days.<sup>13</sup>

On February 4, 2020, while off the coast of Japan, the Diamond Princess cruise ship was identified as having multiple COVID-19–positive patients and placed into quarantine. Of the 3,711 persons on board the ship, all were tested; 712 returned as positive, and 12 later died. There were 338 US citizens evacuated by DoS medical crews on 2 Boeing 747s to quarantine centers in California and Texas where they were received by HHS personnel. There were 14 known positives who were transported on HHS-contracted air flights in an isolation area of the aircraft, and an additional 5 patients were placed into isolation during the flights after developing a fever. Known or suspected positives were taken to local medical treatment facilities upon arrival, and 13 were taken to a treatment facility in Nebraska. Those who became positive or symptomatic during quarantine were also transported to local area hospitals. After local hospital evaluation, some cruise ship evacuees in California were flown via Learjet to medical treatment facilities closer to their home with HHS AETs.

On March 9, 2020, the Grand Princess made an early return to the Port of Oakland with 3,533 persons on board including 21 known to be COVID-19 positive. Most American passengers were debarked from the ship and transferred to federal quarantine centers. Most foreign nationals including many crewmembers were returned to their home country as coordinated between the DoS, foreign governments, and the cruise line. The remainder of the crew and a few foreign nationals would remain quarantined on the ship until repatriated to their home country by the cruise line.

After the US citizens disembarked from the Grand Princess, they were transported by HHS AETs using Boeing 737s to federal quarantine centers in California, Texas, and Georgia. After disbursement to federal centers, the patients were decompressed by a 737, Learjet, or regional jet to their state of residence for screening and home quarantine. During these flights, 2 patients became symptomatic, requiring hospital transfer upon arrival at the destination.

### Considerations for Air Transport

With the unheralded scale of known COVID-19–positive patients and PUIs requiring air transport first from China and later from the 2 Princess ships, new methodologies were adopted from previous recommended techniques.<sup>14,15</sup> The CDC's Guidance for Air Medical Transport of Severe Acute Respiratory Syndrome Patients<sup>16</sup> and Guidance on Air Medical Transport for Middle East Respiratory Syndrome Patients<sup>17</sup> were used as the primary reference document. This document was used on the initial DoS flights from China, and only slight modifications were made over time.

### Isolation Precautions

Efforts were made to transport known positives only with known positives and cohort PUIs with PUIs. The HHS AET crew was limited to the minimum necessary staffing for the various airframe used in accordance with Federal Aviation Administration regulations and NDMS care standards. Infection control precautions focused on the following: source and engineering controls, personal protective equipment (PPE), safe work practices to limited contamination, and containment of the area of potential contamination.

Source control to limit potential droplet transmission distance was used by offering all passengers masks and ensuring that known positive patients wore N95 masks and PUIs wore at least standard surgical masks. Another source control measure taken by passengers on initial repatriation flights from China was the wearing of diapers in order to avoid potential fecal exposure during transport.

Engineering controls used plastic sheeting (Fig. 2) to isolate an area to segregate and treat patients who developed symptoms while airborne. This was primarily at the rear of the plane to allow a separate egress to avoid additional exposure to the nonsymptomatic patients. For long flights, an additional area was created, if possible, in the forward section of the aircraft to allow crew to doff PPE for hydration and lavatory use. Although use was discouraged because of the nature of the enclosed cabin airflow, concessions were made.

Identical PPE was used for known positive and PUI flights for those in close proximity of patients (< 6 ft). Crews used Tyvek suits with booties and a hood, a double layer of gloves (either taped in place or secured with a thumbhole technique to prevent sleeve gap), and either a powered air-purifying respirator or an N95 mask with a face shield (Fig. 3). For those outside the 6-ft range (pilots and flight attendants), a fitted N95 mask and gloves were worn at a minimum; oftentimes, a gown and face shield were also worn.

Safe work practices were used, which included mandatory aircraft surface decontamination, airflow exchanges between flights, and



Figure 2. Isolation Zone Shroud.

lavatories inside the protected area identified for crew use only. Attempts were also made to not recirculate cabin air during the flight. Finally, frequent hand hygiene with an alcohol-based solution was used.

### Airframe Considerations

Multiple fixed wing platforms were used throughout the operation on flights performed by the HHS AET. During the early operation, patients returned from Asia on Boeing 747 cargo planes that were configured with seating. After arriving in the United States, passengers who were identified as PUIs or tested positive for COVID-19 were transported to medical facilities near the quarantine sites. To decompress these facilities, they were later flown via medically configured Lear 35 jets to identified biocontainment centers. Because of the low acuity and ambulatory nature of these patients who were considered stable for air transport to the designated biocontainment centers, they were seated in the rear of the aircraft, providing the maximum isolation from flight and HHS AET crews. In addition, these patients always wore a barrier mask.

During the later operations, patients were initially flown from the point of cruise ship disembarkation to federal quarantine facilities via a Boeing 737. After the establishment of state reception processes, the quarantined evacuees were then transported to their state of residence for home quarantine via a Boeing 737, regional jet, Learjet 35, or charter bus.



Figure 3. Air Evac Team in PPE Pre-Mission.

While transporting patients on the Boeing 737, patients remained in surgical masks, and physical barriers with plastic sheeting were used. There were 2 patients who developed symptoms during transport requiring sequestration in the identified isolation area, evaluation, and transport to medical facilities upon arrival, and both tested positive for COVID-19. The fixed wing aircraft used in the later flights have airflow patterns from rear to front. (There are 747 models with front to rear airflow.) This is obviously problematic when the potentially infectious patients are located at the rear of the aircraft. Of note, rotor wing transport was not used but generally lacks consistent airflow patterns.

There are specific considerations when evaluating an airframe for the transport of a potentially infectious patient. As mentioned previously, cabin airflow is a primary concern. Additionally, the use of high-efficiency particulate air filtration, the location of air outlets, the directional airflow capabilities, and the ability to isolate air mixing between the cockpit and patient care cabin should be considered. Aircraft with reduced postmission airing out time offer an added benefit. It is essential that cabin ventilation remain on at all times, including ground delays. In aircraft with poorly controlled interior airflow, such as rotor wing or other nonpressurized fixed wing aircraft, physical barriers are essential. All personnel should wear N95 or higher respiratory protection or use tight-fitting face pieces capable of delivering oxygen that has not mixed with cabin air.

Ideally, the patient should be positioned as far downwind as possible; unfortunately, this is not possible in most civilian aircraft. Separate lavatory facilities should be identified for patients and crew, with the patient location contained inside their area of occupancy. If using stacked litters, the patients of concern should be positioned in the lowest position in the tier. Ambulatory patients should be seated against the cabin sidewall, and all should wear a surgical mask to reduce droplet contamination.

#### *Equipment and Staffing Considerations*

The medical equipment used was standardized for all patient flights. The NDMS uses a mobile lifesaver kit composed of an advanced life support medical kit, airway bag, and multifunction monitor/defibrillator. It is designed to manage 1 to 2 critical patients during initial stabilization and resuscitation. Because of its diverse capabilities, this kit was sometimes used with an augmented pharmaceutical component. For flights with planned returns to the base of operations, the hard storage cases were often left behind to reduce load. For flights anticipated to require a commercial return, the cases were taken to facilitate secure transport. Clinicians identified PPE requirements before the flight and generally insured they had a minimum of 3 complete sets for unanticipated needs.

Staffing for flights was varied dependent on airframe and patient requirements. Teams used a rolling call list as flight operations for the day varied. They were primarily composed of a physician/advanced practice provider, critical care nurse, and respiratory therapist. For Learjet flights, a combination of 2 clinicians was used.

Fatigue is a known stressor of flight. In addition to altitude, noise, and vibration, several other factors contributed to fatigue for the HHS AET members. Duty days were long; with preflight preparation, unanticipated delays, and long flights, many approached and occasionally exceeded 24 hours. Some crews required an additional day of charter or commercial flights to return to the original base of operations. Steps to mitigate fatigue included adding crews to the staffing rotation to maintain mission tempo and sustain operations. Postmission crew rest periods ranged from 8 to 12 hours before crews reentered the call rotation. Paying special attention to PPE doffing at mission completion to avoid contamination was essential. This was accomplished with a “spotter” when staffing allowed. As a result of the sustained high operational tempo, crews were generally only on deployed rotation for 14 days.

#### *Cruise Ship Patient Destination Transfer*

During the initial hospital decompression involving Americans who had been on board the Diamond Princess, patients were primarily transported to treatment facilities in Nebraska and Washington State. Regarding passengers disembarking from the Grand Princess, the first phase involved those reported as needing medical care before the ship arriving in port; they were received by ambulance and transported by ambulance to medical facilities for further care. The second phase involved screening by medical providers for signs and symptoms of active infection and then being taken for further quarantine at military facilities in California, Texas, and Georgia or to a medical facility for further evaluation and treatment. For the third phase, patients were transferred to their home states, where reception protocols were as diverse as the states by which they were received. Some patients were released to a private vehicle to drive home for isolation, whereas others were escorted by public health officials or law enforcement. In Georgia, 14 Kentuckians were picked up by a chartered bus sent by their state government and returned for home quarantine.

#### *Decontamination*

##### *Waste Disposal*

Dry or fluid saturated waste and sharps containers should be collected in biohazard containers and disposed of as regulated medical waste, ideally at the destination medical facility.<sup>18</sup> This can become problematic if the flight/decontamination terminates at a nonmedical facility or the patient is transferred to a ground service for transport. In that scenario, waste should be retained for disposal at the earliest appropriate location. A suction device or ventilator exhaust should not be vented into the cabin without in-line high-efficiency particulate air or equivalent filtration. Excretions (urine/feces) may be disposed of in the aircraft toilet, but careful consideration should be taken because there are concerns about viral shedding, especially with feces.

##### *Cleaning and Disinfection*

After transporting a SARS-CoV-2/COVID-19 patient, exit doors should be closed and the aircraft air conditioning turned on at maximum capacity for several minutes to allow at least 1 completed air exchange. Nonpressurized aircraft should be aired out, with doors open long enough to insure a completed air exchange. Blowers and high-powered fans should not be used because they could potentially reaerosolize infectious material.<sup>19</sup> Cleaning should be postponed until after the aircraft has been allowed to adequately air out. Cleaning personnel should wear gloves, eye protection, and isolation gowns or coveralls at a minimum; an N95 mask may be beneficial because of concerns over reaerosolization.

#### **Limitations**

There are limitations of this article. A large volume of known positive and PUIs were transported, but the overall acuity was low. Transport of higher-acuity patients may require different methods as found in previous operations.<sup>20</sup> The comprehensive literature review found in the September/October 2019 issue of *Air Medical Journal* was coupled with current CDC recommendations for protocol development in lieu of a formal review. Finally, this review focuses primarily on fixed wing transport, and, as noted, rotor wing or ground transport may require different techniques.

#### **Conclusion**

This concept recommends the best practices to be used while transporting patients with the continued evolution of an infectious respiratory virus, which has stressed global medical systems. Although most patients transported were stable, to the best of our

knowledge, this represents the largest repatriation of potentially infected patients in history. After the dust has settled, time will allow for careful analysis of these actions and those of the health care system in general. We hope at that time to gather additional knowledge and insight to allow for further revision. This represents the movement of over 2,000 distinct patients flown on 39 missions without infection of any transporting HHS air medical evacuation crews.

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