

Long-Range Transportation of Ebola-Exposed Patients: An Evidence-Based Protocol

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Abstract The expanding Ebola pandemic in Western Africa and the assignment of U.S. military troops to provide logistical assistance for Ebola Treatment Units and laboratory testing sites has required the careful development of a plan for the long-range transport Ebola-exposed patients. While the official policy remains “that patients with highly contagious diseases will be treated in place and not transported unnecessarily”, it is anticipated there may be requests for waivers to this policy in the future. The use of a large military transport aircraft (C-17) provides the ability to designate three different zones, including a “green zone” for asymptomatic patients, a “yellow zone” for patients with early symptoms that need additional monitoring, and an “orange zone” for patients who develop symptoms during flight. This protocol allows for the safe transport of multiple Ebola-exposed patients who could develop symptoms during flight, without exposing the remaining passengers or the crew. Additionally, this evidence-based plan ensures the crew members are well-prepared in advance and safely able to transport this unique patient population. While many of the details are unique to this particular military aircraft and the symptoms of Ebola, it is anticipated this protocol can be easily modified to assist with the long-range transport of patients who are exposed to similar communicable diseases transported on other air platforms.

Keywords: Ebola, transportation, primary prevention, hemorrhagic fever, aerospace medicine

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1. Introduction

The Ebola epidemic has become a worldwide challenge, with global implications [1]. Efforts to curb the epidemic in western Africa include the use of special Ebola Treatment Units and appropriate isolation at home or a community setting. According to calculations by the Centers for Disease Control and Prevention (CDC), a 70% admission rate is needed to reverse the exponential increase in the number of Ebola cases [2]. To help achieve this goal, the U.S. government recently assigned a large number of military personnel to Western Africa to set up new treatment facilities and laboratory testing sites [3]. Because of the potential exposure risks, a multi-disciplinary team within the U.S. military developed an evidence-based protocol for the long-range transport of Ebola-exposed and Ebola-diagnosed patients.

The developed processes and training plan will ensure the transport crew and clinical team are well-prepared in advance and safely able to transport this unique patient population. Some of the details of the protocol are unique to a C-17 military transport aircraft and specific Ebola

symptoms. However, as the clinical course and transmission risks of Viral Hemorrhagic Fevers are very similar [4], it is anticipated this protocol could be adjusted to other transport platforms and other viral hemorrhagic fevers as necessary.

The current Ebola outbreak was initially identified in March of 2014, and a Public Health Emergency of International Concern was declared by the World Health Organization Director-General five months later [5]. Just a week prior to that declaration, it was announced two American healthcare workers who had contracted Ebola would be flown to the United States (U.S.) for further medical treatment [6]. The long-range transport of these patients, while successful, represented a fundamental shift in the approach to the international movement of patients diagnosed with high profile communicable diseases.

Ebola is transmitted through physical contact with blood and body fluids and it is theoretically easy to avoid transmission through the careful use of standard, contact, and droplet precautions [7]. However, with Ebolamortality rates as high as 90% [5], transporting patients is a significant threat to health of the aircrew and the medical treatment team.

Long-range transport also adds a tremendous stress on the patient being transported. The stresses of flight are multi-factorial and include decreased partial pressure of oxygen, barometric pressure changes, thermal changes, decreased humidity, gravitational forces, vibration, and noise, which ultimately result in fatigue [8]. For patients in hemorrhagic shock, these particular stresses can significantly worsen their physiologic status. Although Critical Care Air Transport Teams (CCATT) have demonstrated an ability to safely transport critically ill patients [9], this set of critically ill patients come with additional concerns. Additionally, it is not fully understood whether these stresses of flight could escalate the development of viral diseases, or degrade an individual’s immune system and his or her ability to fight an infectious disease.

Accordingly, current U.S. military policy is to treat highly infectious patients “in place”, and avoid unnecessary evacuation back to the U.S. [10]. The policy does allow for the transport of up to two “index cases” using a special isolation unit that transports the individual in a contained environment. However, given the number of potentially exposed personnel and the new expectation that US citizens will be repatriated for treatment, it is anticipated there will be requests for an exception to policy. And, since these patients cannot feasibly be transported individually, it is important to develop a system to ensure the safety of the fellow passengers, even if symptoms (including vomiting and diarrhea) are developed during flight. The importance of having a well-defined process in place to prevent the nosocomial transmission of Ebola is also critical--above and beyond simply having the personal protective equipment (PPE) available [11].

2. Materials and Methods

The protocol was developed by a multi-disciplinary team, consisting of infectious disease physicians, aeromedical evacuation nurses, flight surgeons, logisticians, and policy makers. The team relied on

available resources from the CDC[7,12], policies and procedures from Air Force Mobility Command on Aeromedical Evacuation [13], and available published literature about how to appropriately manage patients with Viral Hemorrhagic Fever [4]. Operational experience from the medical crew from Phoenix Air Corporation, who have transported individual patients diagnosed or exposed to Ebola, and the aeromedical evacuation team members provided a critical component to the development of the protocol. As much as possible, existing equipment and supplies were incorporated into the protocol to assist with mission planning and reduce the logistical burden of this unique mission.

3. Results

The key objective of the protocol was to ensure safe evacuation for both the patients and the crew members, to minimize the impact on the airframe, to minimize the logistical requirement for personal protective equipment while maintaining appropriate precautions, and to be fully prepared for all foreseeable in flight issues. While the CDC has developed guidance for the air medical transport of patients with EVD [12], this guidance does not fully expand on the actual procedures that must be accomplished if an asymptomatic patient develops symptoms during flight, particularly when transporting multiple patients at a time.

The main strategy of the protocol is to separate the airframe into three separate containment zones (Figure 1) in order to transport exposed but asymptomatic patients who could develop symptoms during flight, without exposing the remaining passengers or the crew. Because of the airflow and passenger movement within the aircraft, the physical locations of these zones are particularly important to minimize the exposure between patients who develop symptoms and those that remain symptom-free. Patients with confirmed Ebola as defined by the CDC Case Definition of Ebola Virus Disease will not be allowed onboard a mission with unconfirmed patients.

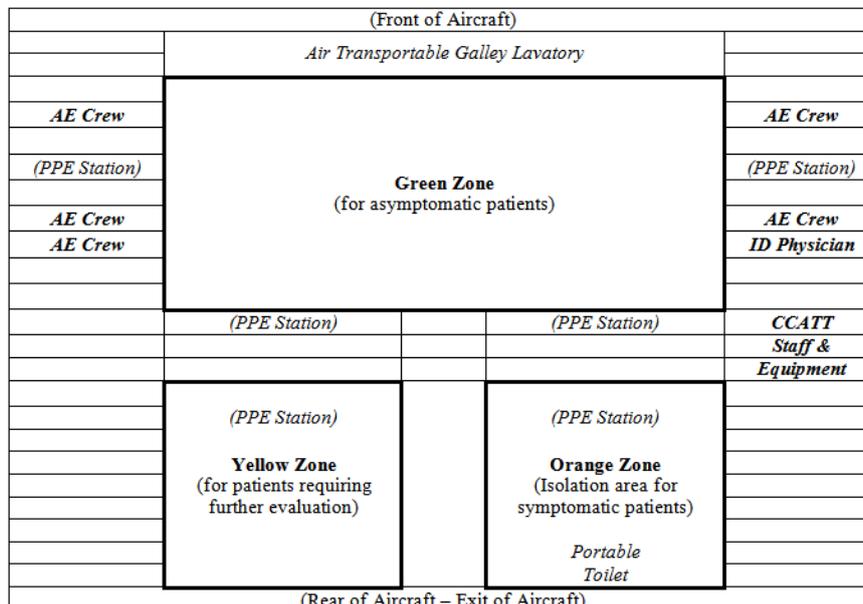


Figure 1. Aircraft Containment Zones

The three designated zones include a “Green” zone, which is a clean environment for asymptomatic patients, as defined in Table 1, that have been exposed to Ebola; a “Yellow” zone which provides a dedicated triage location where a patient that develops early symptoms can be further evaluated; and an “Orange” zone for symptomatic patients, including active vomiting/diarrhea. The “orange” zone also includes an area for medical personnel to decontaminate and remove potentially infected PPE before exiting back into the aircraft; Table 2 provides a summary of the purpose and logistical requirements for each of these zones.

PAPR System is a Powered Air Purification respirator system, which allows the clinician to be fully covered while remaining comfortable and able to breathe.

In addition to these designated zones, specific staff members are needed to ensure the safe patient care is provided during flight. This includes at least two fully trained Aeromedical Evacuation (AE) Flight Nurses and three fully trained AE Flight Medical Technicians; a three-member CCATT (which includes a physician, a critical care nurse and respiratory therapist); and an infectious disease (ID) physician. Depending on the number of patients and length of the mission, this team of nine can be augmented by additional AE Nurses and AE Flight Medical Technicians or other specialty care providers to ensure adequate staffing levels throughout the transport.

The standard equipment needed to transport patients includes an ‘Air Transportable Galley Lavatory’, which consists of two toilets with sinks; litter stanchions with litters and mattress pads for patients that will be laying down; pillows and blankets; medical equipment such as vital signs monitors, a cardiac defibrillator, and suction; and medical supplies which includes gloves, dressings, and syringes. Additional equipment needed for this specific mission include appropriate PPE for caring for patients with Ebola symptoms (including Tyvek/Tychem coveralls, multiple pairs of surgical gloves, rubber outer boots and a Powered Air Purification Respirator (PAPR) system to prevent skin exposure); a patient isolation system; cleaning supplies with a 1:9 dilution of bleach solution, Calla 1452 (Zip-Chem Products, Morgan Hill, CA) and Sani-Wipes (Disposables International, Incorporated, Orangeburg, NY); large biohazard bags to be distributed throughout all zones; and a disposable thermometer for each patient.

3.1. Prior to Departure

Prior to departure, all patient movement requests must be fully entered and validated according to standard protocols, with an additional review of the patient’s medical status by an infectious disease physician or senior physician. This two-step validation process will occur at the Theater Patient Movements Requirements Center–America (TPMRC-A). The TPMRC-A is located at Scott Air Force Base, and responsible for the safe, clinical movement of all patients entering the Patient Movement process, with a physician available at all times for immediate medical consultation for any aeromedical evacuation mission.

Potential mission divert locations will be identified and with required clearances approved prior to aircraft departure. The aircraft will be configured as identified in

Figure 1, with a load plan developed based on the validated patient list along with a fully constructed patient isolation system. Infection control stations, to include biohazard bags and personal protective equipment will be placed throughout the aircraft. These stations will be determined by the medical team during aircraft set-up, and will depend on the number of patients and seating assignments.

Prior to entering the aircraft, the ID physician will screen every patient to confirm they remain asymptomatic, according to current CDC Case Definition for Ebola Virus Disease. Any newly symptomatic patient will not be allowed to enplane, as dictated by the Department of State. Patients with a temperature $\geq 100.5^{\circ}\text{F}$ but not meeting an official definition of fever (usually less than 101.5°F) will remain at the originating site for further evaluation.

A pre-boarding medical briefing will be given to all patients, which includes providing a ‘Mission Pocket Card’ (Figure 2), providing information about post-mission contact information if the patient develops symptoms within 21 days of the flight. All patients will then be escorted directly to their assigned seat by an AE nurse or medical technician.

You were on a flight in which you may have come into contact with patients infected with Ebola. We do not think you are at risk for getting sick with Ebola, but want to give you precautionary guidance and special instructions.

Please review this card carefully and keep with you for 21 days. Inside is information on Ebola. On the back is important information regarding whom to contact/show this card, if you have any questions or become ill.

Please follow the following precautions:

- For the next 21 days, take your temperature every day
- If you develop a fever ($>101.5^{\circ}\text{F}$) or any other symptoms listed inside of this card, contact:
 - Your local flight surgeon on-call (via Command Post)
 - The Air Mobility Command Chief of Aerospace Medicine Dr. _____, Colonel, USAF at [telephone number]
 - Your local medical provider, and have your provider notify the Chief of Aerospace Medicine at number above.

Figure 2. Mission pocket card

3.2. During Flight

During flight, routine care will be provided and documented consistent with current protocols, with the addition of a temperature assessment taken every four hours, using an individual disposable thermometer. The Medical Crew Director (MCD, usually the senior AE flight nurse) will provide a patient status update to the Theater Patient Movements Requirements Center–America (TPMRC-A) by phone patch once cruising altitude is achieved, and one hour prior to landing to receive any new offload procedure directions, if required. The TPMRC-A is located at Scott Air Force Base, and responsible for the safe, clinical movement of all patients entering the Patient Movement process, with a physician available at all times for immediate medical consultation for any aeromedical evacuation mission. The MCD and

the ID physician will be notified immediately of any patient status changes.

The lavatory integral to the aircraft will be dedicated for crew use only. The two toilets on the Air Transportable Galley Lavatory will be available for use by the asymptomatic patients, but will be cleaned with Sani-Wipes before and after every use. If a patient becomes symptomatic, the latrine used by the patient will be clearly marked for use by symptomatic patients only. However, symptomatic patients who are moved to the “orange” area will use a portable toilet located within the “orange” zone. If the second toilet is used by a symptomatic patient, a crewmember will don full PPE and thoroughly wipe down one latrine for use by asymptomatic patients.

If a patient develops any symptoms listed in [Table 1](#), the MCD will be notified immediately, and the clinician caring for the patient will don PPE and escort the patient to the ‘yellow’ area of the aircraft. A fever ≥ 100.5 will be considered a ‘trigger’ that requires further evaluation by the ID physician, and the patient will also be escorted to the ‘yellow’ zone. All patients entering the ‘yellow’ zone will remain in that zone and will receive one-on-one care for the remaining duration of the flight. The infectious disease physician will evaluate and provide

treatment orders as required. After being assessed by the infection disease physician, the MCD will update TPMRC-A of the patients status change and obtain modified offload instructions as required. If the patients exhibit signs/symptoms consistent with the current CDC Case Definition for Ebola Virus Disease, the patient will be moved to the “Orange” zone for the remainder of the mission.

If any patients develop nausea, vomiting, diarrhea or bleeding, the MCD will be immediately notified. The personnel assigned to care for the symptomatic patient will don the appropriate PPE and escort the patient to either the “yellow” zone for additional triage (such as when a patient has nausea that could be related to airsickness), or the “orange” zone for further treatment, as directed by the ID physician. As with other patients in the “yellow” and “orange” zones, the patient will receive one-on-one patient care the remainder of the flight. The ID physician will provide treatment orders as required, and likely include antidiarrheal and antiemetic medications. Any blood/body fluid spills from patients moved to the “Orange” zone will be cleaned by personnel wearing full PPE, regardless of the location within the aircraft.

Table 1. Patient Pre-Departure Briefing

1. The aircrew of this aeromedical evacuation flight welcomes you aboard. In order to ensure your trip is both safe and comfortable, please read the following information concerning your flight.
2. This flight has been augmented with additional medical care providers to address any unforeseen issues en route.
3. In order to ensure the safety of this aircraft and all personnel aboard, please follow the instructions in this brief and any directions provided by the aircrew members.
4. When it is time to board the aircraft, an aircrew member will guide you to your assigned seat and provide additional safety and aircraft orientation.
5. Please inform an aircrew member if you have a history of air sickness
6. Please notify an aircrew member if you need to leave your designated area for any reason (ie. Bathroom).
7. There are Sani-wipes® and gloves located in the comfort pallet bathroom. We ask that you wipe down the sink area and toilet before and after each use.
8. Immediately alert an aircrew member if you feel nauseated, develop a fever, or become ill in any way.
9. In case of airsickness, please use the emesis bags provided to you. Full emesis bags should be placed in the large red plastic bags closest to your seat.
10. If you experience nausea, vomiting or diarrhea while in the bathroom, notify the aircrew by using the bathroom call button.
11. If you develop fever, nausea, vomiting or diarrhea while in flight, you will be escorted to a designated area of the aircraft for further evaluation and treatment. After assessment and treatment, you may be reevaluated and returned to your previously assigned seating or placed in an area where it is easier to assist with your care.
12. Aircrew members may be wearing varying levels of personal protective equipment throughout the flight as required by USAF Aeromedical Evacuation regulations.
13. Please place any materials containing blood or body fluids (facial tissue, paper towels, feminine hygiene items, etc.) in the closest red bio-hazard bags.
14. Finally, the aircrew members of this Aeromedical Evacuation flight wish you a safe and comfortable flight. If at any time you have questions or concerns, please raise your hand and one of the aircrew members will promptly come to your seat.

Table 2. Aircraft containment zones for the transport of Ebola-exposed patients

Zone	Protective Equipment Worn	Available for Immediate Donning	When Used
Green Zone	None (note: PPE serviceable & immediately available)	Tyvek/Tychem coveralls Gloves Rubber outer boots PAPR System with hood	Patient is asymptomatic: Temperature <100.5°F No Nausea or Vomiting No Abdominal Pain or Diarrhea
Yellow Zone	Tyvek/Tychem coveralls Gloves Rubber outer boots	PAPR System with hood	Patient Early Signs: Temperature >100.5°F Diaphoretic Nausea
Orange Zone	Tyvek/Tychem coveralls Gloves Rubber outer boots PAPR System		Patient actively: Vomiting Diarrhea

The ID physician may reevaluate the patient once the nausea has resolved and consider relocating the patient to the “yellow” area if deemed not likely due to Ebola infection; however this patient will not be returned to the ‘green’ zone. Patients with vomiting, diarrhea and/or bleeding may require transfer to the CCATT due to rapid symptom onset or progression, and will be moved to the isolation area in the “orange” zone. Once the ID physician has completed the evaluation of the patient, the MCD will provide an update to TPMRC-A.

Full PPE will be worn by any crew member or clinician entering the “orange” area or coming within six (6) feet of

a symptomatic patient with vomiting, diarrhea, or bleeding. Individuals donning and doffing PPE will use a “buddy-system” to ensure that PPE is put on and taken off appropriately, and will monitor for cross-contamination. When exiting and entering a new zone (ex. from moving from the “orange” zone to the “yellow” zone), PPE must be removed and new PPE applied appropriate for zone to be entered every time.

3.3. Contingencies

If a patient becomes agitated or aggressive during flight, the clinical team will assess and treat for hypoxia, anxiety

and/or apprehension of flight. Reassurance and comfort measures will also be provided, as appropriate. If necessary, onboard security personnel will be alerted and the patient will be physically restrained according to standard policies for the safety of the crew and passengers.

In the event of an aircraft emergency, crew members will follow standard procedures and checklists. If it is necessary to leave the aircraft, the crew will take unused/clean PPE and biohazard bags in egress supplies, and make every effort to follow blood/body fluid precautions following aircraft egress. Depending on the nature of the emergency and status of the patients, the crew will have patients don impermeable suits to reduce potential exposures and aid in identifying patients outside the aircraft. If possible, and when safe to do so, the crew will group patients together and minimize contact with rescuers or other personnel not previously on the mission.

3.4. Deplaning

Patients will disembark from the aircraft, according to current procedures, with the most critical patients deplaning first. If a patient from an “orange” zone require a litter for deplaning, the patient will be placed in a clean Tyvek/Tychemsuit, surgical mask and shoe covers, and assisted onto a clean litter which has been positioned outside of the isolation area and will then be deplaned using standard litter carry procedures; all litter bearers will wear full PPE. Modifications to deplaning procedures may be made based on instructions at the receiving facility and/or the CDC. This will be coordinated with the MCD prior to landing.

3.5. After Arrival

Following the mission, medical crewmembers and/or equipment will be decontaminated per current policy. If no patients exhibit symptoms of disease throughout the entire duration of the flight, no additional decontamination procedures are necessary. If a patient status has changed during flight, the Patient Isolation System will be deconstructed and decontaminated prior to removal from the aircraft. The aircraft and medical personnel may be screened and/or evaluated by the ID physician, if necessary. The contact information for any patients with a change in status will be provided to the infectious disease physician for follow-up contact tracing.

4. Discussion

At this point, this protocol has yet to be tested with the transport of real patients, although the team consists of clinicians with considerable operational experience that were able to thoughtfully incorporate hospital-based protocols into the transport-unique environment. Additionally, the medical crew from Phoenix Air Corporation graciously shared the lessons they have learned from transporting multiple patients that have been diagnosed or exposed to Ebola. Undoubtedly, there will be lessons learned if (or when) patients are transported back to the United States—either for Ebola or some other viral hemorrhagic fever. However, the current protocol provides clear guidance to appropriately plan and prepare

for the assigned mission to ensure the safety of the crew and the passengers.

The dynamic environment of a military transport airplane, such as the C-17, provides several challenges to the safe transport of Ebola-exposed patients who could develop symptoms during flight. Not only are there limitations to the amount of space that is available, there is also limited running water, no integral walls for privacy or isolation, and the surfaces (to include the floor, walls, and ceiling) are not easily cleaned. Once the aircraft is in flight, there is no way to get more personnel, equipment or supplies if there are unanticipated events that occur during flight. These challenges make it essential for the team to be fully prepared for any event; regardless of the likelihood of occurring.

5. Conclusion

The current Ebola outbreak has forced the medical community to address several gaps in existing care, and the challenge of existing protocols that prohibited the movement of patients with highly infectious diseases. While the application of hospital-based infection control practices in a transport aircraft is a difficult challenge for aeromedical evacuation clinicians, the development of a clear and evidence-based protocol provides the guidance to appropriately prepare for the mission. This approach can be tailored for use in the long-range transport of patients exposed to similar communicable diseases in the future.

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Statement of Competing Interests

The authors have no competing interests

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