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Risk Analysis by Failure Modes, Effects and Criticality Analysis and Biosafety Management During Collective Air Medical Evacuation of Critically Ill Coronavirus Disease 2019 Patients



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A B S T R A C T

In March 2020, coronavirus disease 2019 (COVID-19) caused an overwhelming pandemic. To relieve overloaded intensive care units in the most affected regions, the French Ministry of Defence triggered collective air medical evacuations (medevacs) on board an Airbus A330 Multi Role Tanker Transport of the French Air Force. Such a collective air medevac is a big challenge regarding biosafety; until now, only evacuations of a single symptomatic patient with an emergent communicable disease, such as Ebola virus disease, have been conducted. However, the COVID-19 pandemic required collective medevacs for critically ill patients and involved a virus that little is known about still. Thus, we performed a complete risk analysis using a process map and FMECA (Failure Modes, Effects and Criticality Analysis) to assess the risk and implement mitigation measures for health workers, flight crew, and the environment. We report the biosafety management experienced during 6 flights with a total of 36 critically ill COVID-19–positive patients transferred with no casualties while preserving both staffs and aircraft.

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In March 2020, the world faced an unprecedented outbreak of coronavirus called coronavirus disease 2019 (COVID-19).¹ In some French regions, especially in the east, an overwhelming influx of

critically ill patients overloaded intensive care units (ICUs), whereas many other regions were less affected and had available capabilities. Collective air medical evacuations (medevacs) were conducted on board an Airbus A330 Multi Role Tanker Transport (MRTT) from the French Air Force to relieve those ICUs and to ensure the best prognosis for patients.^{2,3} Air medevac of single symptomatic patients with a communicable disease like Ebola virus disease (EVD) had already been performed,⁴ but medevac of multiple patients on an A330 MRTT had never been performed. The situation during the COVID-19 outbreak was different because it required numerous medevacs for

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critically ill patients with acute respiratory distress syndrome involving a virus that little is known about; such a collective air medevac of contagious critically ill patients is a big challenge regarding biosafety. In this work, we review the risk assessment and the situational awareness including both aeronautic and medical constraints. We establish a risk map and proceed to a risk assessment using an FMECA (Failure Modes, Effects and Criticality Analysis) method. We describe the measures implemented to mitigate biohazard for health workers and flight crew on board as well as for the aircraft cabin environment to reach an acceptable risk. We also control the efficiency of our measures by staff health and environmental monitoring. In this article, we report the biosafety management experienced during 6 flights with a total of 36 COVID-19 critically ill patients transferred.

Materials and Methods

Biosafety and biosecurity experts from the French Armed Forces Biomedical Research Institute and chemical, biological, radiologic, nuclear, and explosive (CBRNE) specialists from the French Air Force assessed the risk and considered the feasibility to evacuate critically ill COVID-19 patients with minimal risk of contamination for medical staff, flight crew, and environment, mostly the aircraft cabin. Despite the operational emergency, we conducted a risk analysis based on an FMECA method already in use in some health facilities⁵ to assess and mitigate the COVID-19 transmission risk. We first determined a process map, which listed all the actions undertaken during the mission. Then, we established a risk cartography based on a review of the literature to evaluate the risk of transmission of a communicable disease in an aircraft and the specificity of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission. On-site inspections with the manufacturer (Airbus) helped us to understand the air circulation in the cabin and how it was renewed. Thus, we also considered the need for flight safety and security as well as the medical constraints induced by the care of acute respiratory distress syndrome patients in an aircraft during a flight. The risk of working with a highly pathogenic infectious agent has been evaluated based on guidelines from the French Agency for Food, Environmental and Occupational Health and Safety (Agence Nationale de Sécurité Sanitaire de l'Alimentation).⁶ The MoRPHEE (Module de Réanimation Pour Haute Elongation d'Evacuation [Resuscitation Module for High Elongation Evacuation]) medical kit⁷ transforms the A330 MRTT's cabin into a flying ICU. Our analysis, integrating aeronautical and infectious data, resulted in a set of measures aimed to mitigate the infectious risk in this peculiar environment. The equipment and procedures that we implemented mitigated the risk until reaching an acceptable level previously defined. We chose a step-by-step approach close to the field, which allowed us to check our hypothesis with the already established cabin's configuration. Once we considered that the risk was acceptable, we performed the medical evacuations. The entire staff was medically monitored for early and late symptoms of infection. Environmental samplings using sterile moistened swabs were collected in different spots before and after full decontamination (Supplemental Figure S1). Specific reverse transcriptase real-time polymerase chain reaction targeting RNA-dependent RNA polymerase was used to detect the presence of SARS-CoV-2.

Results

Process Map for Air Medevac of COVID-19 Severely Ill Patients

We listed all actions undertaken by the staff to perform an air medevac of COVID-19 severely ill patients to create a process map (Table 1). This includes actions performed before, during, and after patient transportation from the preparation of the aircraft to the reconditioning.

Table 1

The Process Map of an Air Medevac of Coronavirus Disease 2019 Severely Ill Patients

The staff prepared the aircraft cabin (all devices checked).
The staff put PPE on and were briefed by the staff leader.
The staff leader coordinated the arrival of the patients on the aircraft.
The staff transferred on the aircraft stretcher and put all medical devices in place.
The staff assessed the patients and prepared them to take off.
The staff prepared to take off (sit down and lock the belt).
After takeoff, the staff took care of patients (moving from one patient to another, patient monitoring, and ICU treatments including possible high-risk gestures on respiratory tract).
At the end of the flight, the staff prepared the patients for landing.
The staff prepared for landing (sit down and lock the belt).
After landing, the staff prepared the patients for transfer.
The staff leader coordinated the departure of the patients from the aircraft.
The staff transferred from the aircraft stretcher to the ambulance stretcher and turned all medical devices off.
The staff decontaminated all medical devices.
The staff undressed PPE and left the aircraft.
A specialized team decontaminated the aircraft cabin and managed wastes.
After full decontamination, staff was debriefed and reconditioned all material.

ICU = intensive care unit; PPE = personal protective equipment.

Risk Analysis: From the Published Data on Air Transportation of Patients With a Communicable Disease to the COVID-19–Specific Risks

Aircraft transportation has been described as a cause of tuberculosis,⁸ measles,⁹ or severe acute respiratory syndrome¹⁰ infection spread between travelers. Thus, in 2007, the US authorities published a public health “Do Not Board” list to avoid people who are at risk to be contagious from boarding commercial flights.¹¹ As a result, in 2015, almost 400 passengers had been placed on federal public health travel restrictions for getting tuberculosis or measles,¹² and between January 2014 and December 2016, 160 passengers had been travel restricted because of documented high-risk exposure to EVD, Lassa fever, or the Middle East respiratory syndrome coronavirus.¹³ However, although the risk of infectious disease transmission has been described between passengers during commercial flights, there are less scientific data for medical transportation related to massive evacuations of contagious patients. Nevertheless, during the West-Africa EVD outbreak, at least 33 patients were evacuated to the U.S. or Europe and two patients with Lassa fever were evacuated from Togo in 2016, but, to the best of our knowledge, all were medical evacuations performed in a dedicated confinement unit, with a unique symptomatic patient on-board.^{4,14,15}

There is no international guideline regarding the protection of the aircraft in a collective evacuation situation. The Centers for Disease Control and Prevention and the European Centre for Disease Prevention and Control only edited recommendations for air medevac of patients with EVD.^{16,17} Briefly, both institutions recommended the use of an isolation unit or the demarcation of a “dirty” perimeter where personal protective equipment (PPE) has to be used and specific decontamination actions have to be performed. Minimizing the opportunities of exposure by limiting needle use, using disposable equipment, and avoiding aerosol-generating procedures was also encouraged.

However, these recommendations for EVD cannot be directly applied to the transportation of critically ill patients with a high risk of airborne transmission. At the time of the first evacuations of patients with COVID-19, the specific mechanism of SARS-CoV-2 transmission in detail. The only way to assess the risk of transmission of this new coronavirus in a complex and confined environment was to refer to scientific data about the transmission of closely related viruses. Lessons learned from the 2003 SARS-CoV-1 outbreak show that patients infected with a coronavirus are at high risk of super-spreading events by multiple ways of transmission. Indeed, the 20 guests of the Metropole Hotel in Hong Kong had no direct contact with the index case patient and were likely infected through

environmental contamination by body fluids or respiratory droplets including aerosolization while passing through these same areas.¹⁸ A similar airborne transmission was also observed in a large housing complex in Hong Kong due to a hydraulic action inside drainage pipes.¹⁹ Nosocomial clusters have also been described, notably in Toronto where 128 cases were described in a hospital.²⁰ These events, especially those related to airborne transmission, are also described in the current outbreak,²¹ such as in the Diamond Princess cruise ship where all transmission modes might have been involved.²² Indeed, the persistence of the coronavirus in the environment has been tested in experimental conditions. Under certain temperature and humidity conditions, the SARS-CoV-2 responsible for COVID-19 might remain viable in aerosols for more than 3 hours with a half-life of 1 hour. It has also been found to be viable on plastic and stainless steel up to 72 hours with a half-life of several hours.²³ These data are corroborated by studies on previous human coronaviruses SARS-CoV-1, Middle East respiratory syndrome coronavirus, and endemic human coronaviruses, which can persist on inanimate surfaces for up to 9 days but remain sensitive to disinfection procedures.²⁴

Risk Analysis: Contextual Assessment From the Aircraft Configuration to Constraints for Health Workers and Flight Crew

The Airbus A330-MRTT is an aerial refueling tanker aircraft used by the strategic air force and based on the civilian Airbus A330-200. Part of the aircraft cabin can be transformed into a medical zone.⁷ This capability of collective strategic medevac, known as MoRPHEE, was designed to evacuate severely injured war casualties and originally used the Boeing KC-135. The A330-MRTT with the MoRPHEE kit was conceived to be able to adapt to multiple scenarios, including contamination by CBRNE agents. The A330-MRTT with the MoRPHEE

kit provides the level of care of a flying ICU and complies with the aeronautical security regulations. Six critically ill patients in addition to 8 other patients can be transported simultaneously with a medical crew composed of 3 ICU physicians, 2 flight surgeons, 3 anesthetic nurses, 3 flight nurses, and 2 nurses trained in emergency care.²⁵ However, it was not designed to take care of patients with a communicable disease; the COVID-19 pandemic was its first use in operational conditions ever.

The missions aimed to evacuate COVID-19 critically ill patients needing permanent monitoring without any information about their capability for SARS-CoV-2 dissemination. Despite the presumed or potential patient's contagiousness imposing biosafety measures, medical and aeronautic standard security procedures had to be followed. Clinical parameters and aeronautic data are detailed in separate publications.^{2,3} Pilots should not be exposed to infectious risk and should fly the aircraft as usual. The cabin flight crew had to be able to secure the aircraft, especially during the boarding and disembarking phases. Health workers had to be able to perform technical interventions and to control patient stability for several hours despite the infectious risk. Both health workers and flight crew should have the possibility to rest in a “clean” area.

Mitigation of the Risk in the A330 MRTT: Zoning, Decontamination, Dedicated Procedures, and Training

We have adapted the Airbus A330 MRTT by creating different areas in the aircraft cabin (Fig. 1). The MoRPHEE medical area was considered as “dirty” and separated by a vinyl partition from the front of the aircraft including the cockpit and the back of the cabin. Air processed by high-efficiency particulate air filters entered the cabin from overhead distribution outlets and left the cabin toward the ground outflow grills (Fig. 2A) with minimal forward and backward

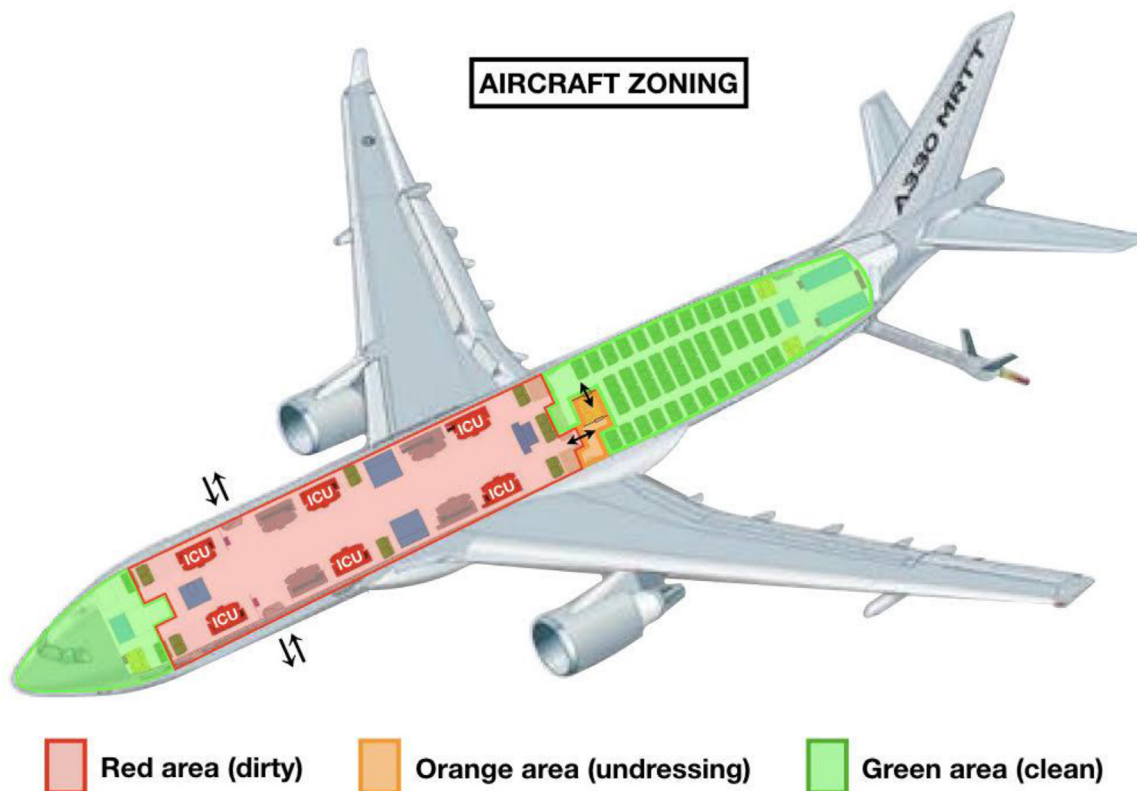


Figure 1. The creation of different areas in the aircraft cabin. An A330 MRTT equipped with the MoRPHEE kit. The green area is the “clean” area, the red area is the “dirty” area, and the orange area is the transition area with the air lock. (Adapted from the technical data sheet Airbus A330 MRTT PHENIX French Air Force).

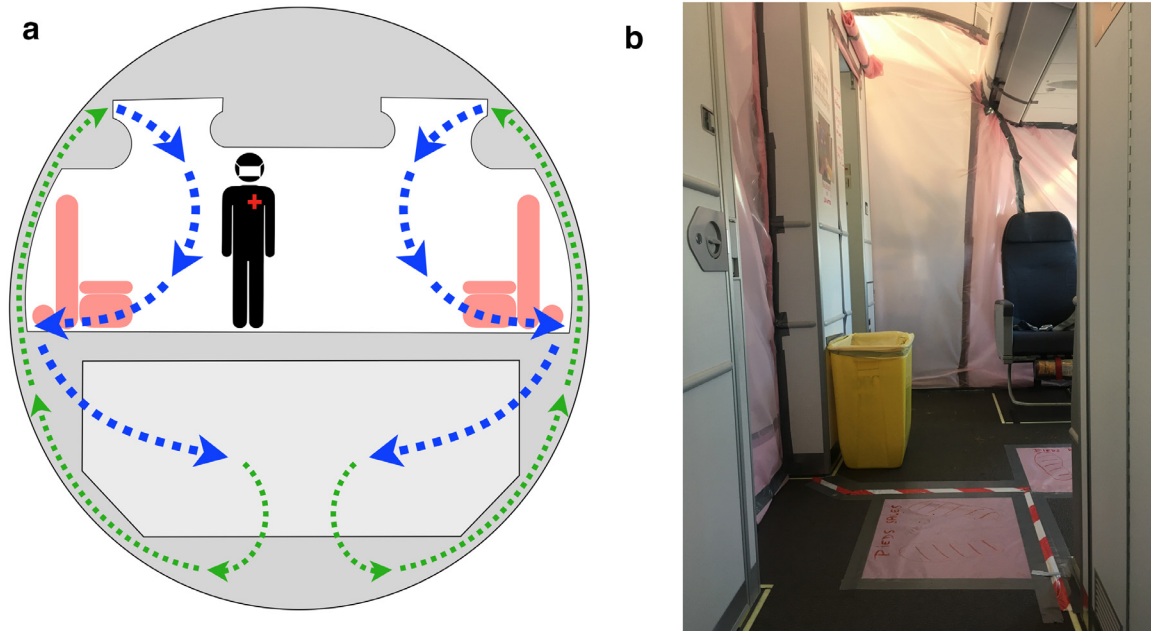


Figure 2. Biosafety in the cabin. A, Airflow in the cabin. B, Air lock in the left back of the “dirty” area.

airflow.²⁶ The air was renewed every 3 minutes. The airflow in the cabin was advantageous to contain the possible dissemination of viral particles. The front and the back of the aircraft were considered as “clean.” We used the “clean” area in the back as a safety zone to allow the medical staff and the flight crew to rest. Thus, we created an intermediary area with an air lock to allow the personnel to go out the “dirty” area using biosafety procedures (doffing PPE) and to return. For that purpose, we used the disabled toilet to create a vacuum air lock in which the air was renewed every 34 seconds thanks to the mechanical ventilation system (Fig. 2B). We blocked all the apertures in the door on the “dirty” side of the air lock so that the air entering only came from the “clean” area. Decontamination of the “dirty” area was performed in 2 steps with aircraft-approved products. First manual cleaning disinfection of all surfaces was performed, focusing on the most frequently touched areas, followed by an application of disinfectant by a fogging machine.

All personnel in the “dirty” area were equipped with standard PPE, notably filtering facepiece 2 (similar to N95) masks. However, before the first evacuations, neither health workers nor the flight crewmembers were used to wearing such equipment, even if the flight crew had already been trained in CBRNE procedures. We had to set up dedicated procedures, especially for the use of the air lock and to train all personnel to work with this constraint. These PPE and procedures also raised safety issues by reducing the ergonomics of routine medical procedures and increasing staff stress. Therefore, we set up specific training and debriefing after every mission. Actions involving the respiratory system, such as cardiopulmonary resuscitation, are known to be high-risk situations for the transmission of coronavirus.²⁷ Thus, we followed the French guidelines²⁸ to transfer patients with minimum risk of aerosolization (patients intubated under curare administration, ventilated and aspirated only with closed and filtered systems, and shutoff and clamping mechanical ventilation systems during patient transfer). Throughout the medevac, a dedicated biosafety team was present to ensure that procedures were followed.

Risk Analysis

Our risk analysis was limited to the management of patients by our flying team and separated between occupational risks and

environmental contamination risks. It excluded the ground teams as well as the analysis related to aeronautical risks. All risks were quantified in FMECA (Table 2) using the risk rating scale (Table 3) before and after mitigation. The coefficients for each risk modality were assigned by a consensus of at least 3 experts. A risk priority index at 20 or less was considered as low and did not require any further mitigation. An index between 21 and 40 was considered as middle and needed some supplementary measures, whereas a superior index at 40 was considered as not acceptable and prevented the continuation of the mission. Despite several risks initially identified as not acceptable with index values up to 80 (for a maximum of 125), we managed to reduce all risks to an acceptable level. The higher residual risk concerned mostly contamination (especially by contagious personnel) and injuries by fall.

Medical and Environment Monitoring Leading to the Validation of the Biosafety Area

The first flight occurred on March 18th followed by 5 other flights on March 21st, 24th, 27th, and 31st and April 3rd. Six ICU patients were transported in each flight for a total of 36 patients. During the second flight, 68 environmental samples were collected, and all of them were negative. These results were especially important for the safety zone, where health workers and flight crew had the possibility to rest. Because of the unprecedented nature of this zoning, we chose a step-by-step implementation with a prototype in the first flight before a definitive version during the second mission. Finally, we used this safety area to rest after patients had been disembarked only from the third medevac when we received the results of our samplings. All in all, 14 people had been exposed only in the “clean” zone and 28 in both the “dirty” and “clean” zone during several hours per mission (4 hours, 30 minutes – 6 hours, 30 minutes). Fourteen days after the last flight, none of them experienced any symptoms; hence, none were tested by polymerase chain reaction (not indicated for massive and systematic testing at that time).

Discussion

In this article, we presented the implemented biosafety measures for the first-ever collective air medevac of critically ill COVID-19 patients. Our objective was to establish working conditions as close

Table 2
Risk analysis by FMECA (Failure Modes, Effects and Criticality Analysis)

Identified hasard	Modality	Possible effect	Likelihood	Severity	Detectability	Risk priority index	Mitigation	Residual likelihood	Residual severity	Residual detectability	Final risk priority index				
Occupational risk															
Risk of occupational injury or disease	By cutting	Injury	3	2	2	12 ●	Wearing PPE (∇L, ∇S, ∇D) Safety area (∇L)	4	1	1	4 ●				
	By projection in the eyes		3	3	2	18 ●	Wearing PPE (∇L, ∇S, ∇D) Safety area (∇L)	4	1	3	12 ●				
	By traumatic causes (fall, heavy load carrying...)		2	3	2	12 ●	Wearing PPE (∇L) Safety area (∇L)	3	3	2	18 ●				
	By organisational and procedural problems		2	3	3	18 ●	Post mission debriefing (∇L, ∇D)	1	3	2	6 ●				
	By deviation from the protocols (tedious or unsuitable rules)		3	3	3	27 ●	Staff training (∇L, ∇D) Post mission debriefing (∇L, ∇D)	2	3	2	12 ●				
	By stress	Psychic injury or mental illness	3	3	3	27 ●	Wearing PPE (∇L, ∇S, ∇D) Safety area (∇L) Staff training (∇L, ∇S) Post mission debriefing (∇L, ∇S, ∇D)	2	2	3	12 ●				
	By wearing PPE during a long time		Fatigue, headache, renal colic, skin irritation ...	4	2	2	16 ●	Safety zone (∇L, ∇S) Staff training (∇D)	3	1	1	3 ●			
Risk of staff contamination by the patient	By a direct contact of viral material with the skin (secondary contamination)	Staff infection	3	4	3	36 ●	Wearing PPE (∇S) Operating procedures (∇L) Safety area (∇L)	2	1	3	6 ●				
	By a projection of viral material in the face		3	4	2	24 ●									
	By droplet from the patient		4	4	4	64 ●									
	By an inhalation of aerosolised virus		3	4	4	48 ●									
	By organisational and procedural problems		2	4	4	32 ●	Post mission debriefing (∇L, ∇D)	1	4	2	8 ●				
	By deviation from the protocols (tedious or unsuitable rules)		3	4	4	48 ●	Staff training (∇L, ∇D) Post mission debriefing (∇L, ∇D)	2	4	2	16 ●				
Risk of staff contamination by other staff members	By droplet or aerosol		4	4	4	64 ●	Social distancing (∇L) Wearing surgical mask (∇L) Safety area (∇L)	1	4	4	16 ●				
	By fomite		3	4	4	48 ●	Hand hygiene (∇L) Safety area (∇L)	1	4	4	16 ●				
Risk of environmental contamination															
Risk of contamination of the safety zone	By the staff (hand-held) contamination	Staff infection	4	4	3	48 ●	Wearing PPE (∇L) Operating procedures (∇L)	1	4	3	12 ●				
	By the staff (infected and contagious personnel)		4	4	4	64 ●	Wearing surgical mask (∇L) Decontamination by a dedicated team (∇L)								
	By aerosolised viral particles		3	4	4	48 ●									
	By aerosolised viral particles (explosive depressurisation)		1	4	2	8 ●	Give to all staff a spare FFP2 mask in case of need (∇S)					1	2	2	4 ●
Risk of contamination the environment (airport facilities)	By the staff (hand-held) contamination	Staff or other personnel infection	4	5	3	60 ●	Wearing PPE (∇L) Operating procedures (∇L)	1	5	3	15 ●				
	By the staff (infected and contagious personnel)		4	5	4	80 ●	Wearing surgical mask (∇L) Decontamination by a dedicated team (∇L)								
	Failure to decontaminate the aircraft		2	5	4	40 ●	Decontamination by a dedicated team (∇L) Control by environmental sampling (∇D)					1	5	3	15 ●
	Failure in waste management		3	5	3	45 ●	Waste management by a dedicated team (∇L, ∇D)					1	5	2	10 ●

Table 3
Risk Rating Scale for Likelihood, Severity, and Detectability

Parameter	Degree		Coefficient
Likelihood	Frequent	Certain that the failure will frequently occur	5
	Likely	Frequent failure	4
	Occasional	Failure occurred occasionally with a similar process	3
	Rare	Could occur and has been observed once	2
	Unlikely	Could occur but has never been observed	1
Severity	Deadly	Can cause death for human or global exposure/dissemination	5
	Serious	Can cause very serious or irreversible injuries for human or mass exposure/dissemination	4
	Average	Can cause significant injuries for human or very likely exposure/dissemination	3
	Benign	Can cause mild injuries for human or a very limited risk of exposure/dissemination	2
	Unlikely	Could unlikely cause mild injuries for human or no risk of exposure/dissemination	1
Detectability	Impossible	Detection is not possible.	5
	Difficult	An experienced person needs to verify several parameters and interpret a complex situation to highlight the possible occurrence of the event.	4
	Moderate	An experienced person or a measurement/test can detect that the event could occur.	3
	Easy	There are multiple factors that could alert the personnel before the event occurs.	2
	Obvious	A novice could easily detect the event before it occurs.	1

Risk priority indexes are calculated by multiplying the coefficient for likelihood, severity, and detectability.

as usual for health workers while protecting them and the aircraft from SARS-CoV-2. The challenge was the absence of recommendations or guidelines to evacuate multiple patients with an emerging communicable disease¹⁵ and the operational emergency, which forced us to quickly develop an innovative solution, even if we did not know a lot about the virus or its propagation. Thus, we performed a risk analysis based on the FMECA method by assessing the published data on infectious risk and air transportation as well as coronaviruses' specific mode of transmission.

The literature published after our missions confirmed the increased risk of COVID-19 transmission during air travel.²⁹ Even if simulations in several aircraft have shown a low risk of aerosol dispersal during the flight,³⁰ multiple outbreaks have occurred during flights, especially long ones and despite low occupancies and prevention measures including wearing masks in some of them.^{31–35} Clusters have also been described in other confined spaces like restaurants,³⁶ conference rooms, or public transportation,³⁷ and health care facilities have been proven to be among the most contaminated areas by aerosol or contamination transfer.^{38–42} Moreover, the virus can survive up to days on surfaces depending on the conditions.^{43–46}

However, by integrating some contextual data from the aircraft configuration and the constraints of health workers and flight crew work, we set up dedicated biosafety procedures and trained all staff members to efficiently mitigate the risk and protect both the staff and the aircraft. The most innovative measure was without contest the compartmentalization of the aircraft with the creation of different areas in the cabin to separate the working zone considered as “dirty” from a “clean” zone, which was considered a safety area. We implemented it step by step and used it only after some adjustments and receiving the results of the environmental samplings to ensure that the risk in this area was not higher than the risk in the general population. We completed this compartmentalization with the systematic use of complete PPE with filtering facepiece 2 masks, widely praised by all staff despite a loss of workplace ergonomics. These measures have since been established as the standard for COVID-19–positive patient management,⁴⁷ and the CBRNE defense culture of the strategic air force has facilitated their implementation. Since then, several studies have shown the relevance of this choice, including a meta-analysis showing the general efficiency of masks in preventing respiratory viral infections including human coronaviruses⁴⁸ but mainly epidemiological arguments showing the association between nosocomial transmission of SARS-CoV-2 and the use of N95 masks in a health care worker population in China.⁴⁹ Even if N95 or surgical

masks do not always provide full protection,⁵⁰ masks efficiently reduce virus shedding in exhaled breath⁵¹ and have been proven to be effective at reducing transmission in a variety of settings.^{52–55} In an airplane, wearing a mask appears to provide a certain degree of protection.^{56,57} Thus, wearing a surgical mask for awake patients in all circumstances and for all staff in the safety area contributed to mitigating the spreading risk.

The initial assessment identified high risks for staff and for the environment, with several risk priority indexes exceeding 60 for a maximum possible at 125. The highest risk was a possible contamination of the staff or the environment by the patient or other staff members, which is highly problematic on a military air base.⁵⁸ The mitigation measures we implemented managed to lower the risk to an acceptable level with all risk priority indexes less than or equal to 20. We maintained this assessment even if we did not study the dispersion of the virus in the air of the cabin by atmospheric sampling, whereas the spread by aerosol is 1 of the most difficult to contain.⁵⁹ Moreover, in the current situation, reverse transcriptase real-time polymerase chain reaction tests should have been considered before the mission for all staff, but at this time in France they were reserved for symptomatic patients with severe forms of the disease. Thus, the highest residual risk was a contamination of the environment, especially the airport facilities by an infected staff. This risk was identical to that of staff who have no professional exposure (eg, an airport staff member). This meant that we managed to efficiently mitigate all additional risk due to the unusual nature of the mission. As a result of the measures we put in place, especially due to PPE wearing, certain risks increased notably for occupational risk, such as traumatic injuries, illness, or stress. Despite our efforts, traumatic injuries were the second residual risk index, but, fortunately, none of our staff experienced any injury.

We evacuated 36 patients over a long distance with no casualties while preserving both staff and aircraft. We did not find any sign of infection among all personnel present in the aircraft after monitoring them during 14 days after the last flight. The negativity of all samplings validated our biosafety measures, especially decontamination procedures. This was especially important because after this medevac the aircraft had to pursue all its other missions ranging from aircraft refueling to strategic medevac of injured soldiers. However, critically ill patients are suspected to have lower viral charges than mild to moderate cases⁶⁰ and might be at lower risk than patients with an early form of the disease.⁶¹ Indeed, it has already been described that in 3 resuscitation rooms, only 1 among the 3 patients had

contaminated his environment.⁶² Fortunately, SARS-CoV-2 remains very susceptible to a wide range of disinfectants,⁶³ and their persistence could affect the virus survival on surfaces⁶⁴ as confirmed in China where SARS-CoV-2 RNA was only found in the sewage of hospital isolation wards routinely wiped.⁶⁵ However, we recommend performing supplementary sampling in case of transportation of symptomatic and conscious patients who could be more at risk of environmental dissemination. We did not test our organization in a long-range flight with staff turnover implying multiple back and forth movements in the “clean” zone and more risk of contamination.

Conclusion

Zoning the aircraft and developing appropriate operating procedures created a safe work environment in the A330 MRTT during the evacuation of COVID-19 critically ill patients. Both medical staff and aircraft were preserved during these missions. Furthermore, the existence of a “clean” zone, which allows the medical staff to rest, makes repeated flight or long-range flights possible with maximum safety. The methodology of the infectious risk assessment used could be extended to any situation at risk of contamination, especially with an emergent pathogen. As previously evoked,⁶⁶ this article illustrates the contribution of infectious risk management specialists in the conduct of operations related to a major biological crisis.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amj.2021.10.006>.

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