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Original Research

## Analysis of European Air Medical Evacuation Flights of Coronavirus Disease 2019 Patients

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## A B S T R A C T

**Objective:** As part of the humanitarian response to the coronavirus disease 2019 (COVID-19) pandemic, the German and French Armed Forces provided air transport for patients from overwhelmed regional hospitals in Italy and France. The objective of this study was to analyze the characteristics of the missions and the medical conditions of COVID-19 patients transported during an air medical evacuation on fixed wing aircraft in March and April 2020.

**Method:** This was a retrospective analysis of transport records as well as other documents for 58 COVID-19 patients requiring artificial ventilation.

**Results:** The median age of the transported patients was 61.5 years, and 61% of them had preexisting medical conditions. They had been ventilated for a median of 5 days and experienced the first symptoms 18 days before transport. The patients flown out of France had less days of ventilation before flight, a lower end-tidal carbon dioxide level at the beginning of the flight, and a lower Charlson Comorbidity Index. There were also some differences between the ventilation and the flight level flown by the 2 air forces.

**Conclusion:** The intensive care transport of ventilated COVID-19 patients requires highly qualified personnel and appropriate equipment and should be planned appropriately.

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In December 2019, a new virus-induced, interstitial pneumonia appeared in Wuhan, People's Republic of China. In early January

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2020, Chinese scientists identified a novel coronavirus (severe acute respiratory syndrome coronavirus 2)<sup>1,2</sup> that is transmitted between people via droplets.<sup>3</sup> Klicken oder tippen Sie hier, um Text einzugeben. The outbreak quickly developed into an epidemic in China in January 2020 and spread rapidly across the globe. The World Health Organization established the name “coronavirus disease 2019” (COVID-19) and declared it a pandemic on March 11, 2020.

In Europe, Italy, France, and Spain were hit particularly hard between February and April 2020.<sup>4,5</sup> The capacities of the various health care systems, above all with regard to intensive care beds and especially ventilators, were placed under immense pressure and were in some cases overwhelmed. Critically ill patients were moved not only to hospitals within the same country that had available ventilators but also to suitable hospitals in foreign countries. This was done by ground-based (intensive care) transport vehicles and air

medical evacuation (AE) using both helicopters and airplanes. There was a lack of scientific knowledge regarding the AE of COVID-19 patients by airplane at the beginning of this pandemic. Drawing conclusions from the AEs performed in spring 2020 is a prerequisite for improving future transports of COVID-19 patients. The objective of this study was to analyze the characteristics of the missions and the medial conditions of COVID-19 patients transported during a collective AE on fixed wing aircraft by the French and German Air Forces in March and April 2020.

## Methods

From March 18 to April 3, 2020, the French and German Air Forces transported in total 58 patients (Table 1). The French Air Force used an Airbus A330 Multi-Role Transport Tanker (MRTT) and has flown a total of 36 French patients in 6 missions from northeast France. The Airbus A330 MRTT is a fixed wing aircraft specially reconfigured for the transport of patients with transport units named “MORPHEE” for the French Module de Réanimation pour Patient à Haute Elongation d’Evacuation.<sup>6</sup> The AE version includes up to 6 intensive care patient transport units, ensuring a modern standard of intensive care.

The medical team includes 3 anesthesiologists, 1 of them being the medical director, 3 anesthetic nurses, 2 flight surgeons, 2 nurses, and 2 flight nurses.<sup>7</sup> The medical team was reinforced in the pandemic context by 2 physicians and 2 biomedical technicians. All the practitioners were members of the French Military Medical Service (FMMS).

The German Air Force used an Airbus A310-304 MRTT<sup>8</sup> and has flown a total of 22 Italian patients from Bergamo, Italy, to Germany. The patients were chosen on the basis of decisions by Italian authorities before each flight. The AE version includes up to 6 patient transport units, ensuring a modern standard of intensive care. In addition, the Airbus A310-304 MRTT can also transport a further 38 stretcher patients. However, these patients cannot be provided with intensive care or mechanical ventilation. In both aircraft types, patient transport units are used for monitoring and ventilating intensive care patients. For every 2 patients, there is an intensive care team consisting of an anesthesiologist and an anesthetic or intensive care nurse who provide care before, during, and after the flight. The medical team also includes a medical director, a medical crew chief, a medical technician specially trained for such aircraft, and at least 4 paramedics. A recently published article describes in detail the air medical transport of intensive care patients.<sup>8</sup>

Our analysis is based primarily on an evaluation of the intensive care transport records used during flight (these records are based for France on recommendations of the French Data Protection Authority [Commission Nationale d’Informatique et Libertés, CNIL number MR

0509270320] and for Germany on recommendations of the German Interdisciplinary Association for Intensive Care and Emergency Medicine, version 1.1). These records were used by the attending intensive care physician after the patient was handed over by the national emergency service at the airport of embarkation until the patient was handed over to the regional emergency service at the airport of debarkation. Data from the intensive care transport records were entered into SPSS 24 statistics software for Microsoft (Redmond, WA) Windows (IBM Corp, Armonk, NY), which was used to compute descriptive statistics. During entry, data were checked for plausibility and, if necessary, were corrected in accordance with information in the form fields or in-flight data of the intensive care transport record. If information was missing, the medical personnel was contacted directly. In addition to the intensive care transport records, further information from the patient movement requests was gathered as well as any doctor’s referrals from the releasing hospitals. In the analysis, the flight times documented by the European Air Transport Command were also included to take this factor into consideration. (The European Air Transport Command is a multinational command center of the French, Dutch, Belgian, German, Spanish, Luxembourgish, and Italian Air Forces in Eindhoven in the Netherlands. Its main task is the coordination and operational control of the air transport and aerial refueling capabilities as well as the AE evacuation operations of the participating states.)

The flight time (ie, the transport-in-air time) is the time between takeoff and landing. If a patient had a second flight after a stopover (eg, patients on the flight to Cologne Bonn Airport on March 29, 2020), we combined the flight times of the 2 flights.

The treatment time of patients (transport time) was calculated based on the records of vital signs as the difference in time between the first and the last entry. It started when the patient was handed over by the local emergency service and concluded at the destination airport when the patient was transferred to the regional emergency service for further transport to the destination hospital. These records were checked for plausibility with the flight times provided by the European Air Transport Command. The ratio between the transport time and the transport-in-air time is the transport-in-air/transport time (TAT) index.

All tables are indicated as medians with the interquartile range. We planned to analyze the results in total and for 2 prespecified subgroups defined as the patients transported by the FMMS (the French group) and the German Air Force (the German group). All parameters are shown for all 58 patients in total and for the patients transported by the FMMS and the German Air Force separately. Differences between the 2 subgroups were analyzed by the chi-square test or the Mann-Whitney *U* test with a primary level of significance of  $P < .05$ .

**Table 1**

The flights conducted, the origin and destination airports, the number of patients transported, the flight time, and the cruising altitude

Date	Aircraft	Flight	Patients	Flight Time (h)	Altitude	Cabin Altitude
French Air Force						
March 18, 2020	Airbus A330 MRTT	BSL-LFMI	6 French	0:52	30,000 ft	4,900-8,800 ft
March 21, 2020	Airbus A330 MRTT	BSL-BOS	6 French	1:10	30,000 ft	4,900-8,800 ft
March 24, 2020	Airbus A330 MRTT	BSL-BES	6 French	1:13	30,000 ft	4,900-8,800 ft
March 27, 2020	Airbus A330 MRTT	BSL-BOD	6 French	1:02	30,000 ft	4,900-8,800 ft
March 31, 2020	Airbus A330 MRTT	BSL-HAM	6 French	1:17	30,000 ft	4,900-8,800 ft
April 3, 2020	Airbus A330 MRTT	LUX-TLS	6 French	1:15	30,000 ft	4,900-8,800 ft
German Air Force						
March 28, 2020	Airbus A310-304 MRTT	BGY-CGN	6 Italian	1:05	20,000 ft	2,380 ft
March 29, 2020	Airbus A310-304 MRTT	BGY-HAM (-CGN) <sup>a</sup>	6 (2) Italian	1:25 (+0:40)	20,000 ft	2,380 ft
April 1, 2020	Airbus A310-304 MRTT	BGY-CGN	4 Italian	1:05	20,000 ft	2,380 ft
April 3, 2020	Airbus A310-304 MRTT	BGY-CGN	6 Italian	1:10	20,000 ft	2,380 ft

BES = Brest Airport; BSL = Basel Airport; BGY = Bergamo Airport; CGN = Cologne Bonn Airport; HAM = Hamburg Airport; LFMI = Bordeaux Airport; LUX = Luxembourg Airport; TLS = Toulouse Airport; STR = Stuttgart Airport; SXB = Strasbourg Airport.

<sup>a</sup> Four of the 6 patients on the flight on March 29, 2020, were transported to Hamburg Airport; the remaining 2 patients were then flown to Cologne Bonn Airport.

On account of multiple testing, the level of significance was adjusted by means of the Bonferroni correction ( $P < .0025$  for 20 parameters).

Our analysis was performed as part of the ministerial research mission of the German Air Force Centre for Aerospace Medicine. No additional medical, diagnostic, or therapeutic procedures were conducted for this study. It involved only the retrospective analysis of anonymized medical record data. The data protection officer in charge approved the use of anonymized medical data for scientific analysis. The local ethical committee decided that a formal approval was not required.

## Results

A total of 40 men and 18 women (median age = 61.5 years; range, 45.0–78.0 years) have been transported on AE flights for COVID-19 patients. Thirty-five patients (61%) had documented preexisting medical conditions (Table 2).

For 20 patients, the onset of symptoms was communicated by the national emergency service when the patient was handed over or was extrapolated from the patient movement request or other medical records; the median value was 18.0 days (range, 6–35 days) before transport. All patients received sedative and analgesic medications and were mechanically ventilated. Fifty-three patients (90%) had an endotracheal tube in place, and 5 had a tracheostomy (10%). Mechanical ventilation started at a median of 5 days before transport (range, 1–28 days). The patients flown by the FMMS had less days of ventilation before flight (4 vs. 10 days,  $P < .001$ ), were mostly volume-controlled ventilated, and had a lower end-tidal carbon dioxide (ETCO<sub>2</sub>)

at the beginning of the flight in comparison with the patients flown by the German Air Force (30 vs. 42 mm Hg,  $P < .001$ ).

The peripheral oxygen saturation at the beginning of the flight for all patients together was 96% (range, 88%–100%), the ETCO<sub>2</sub> was 33 mm Hg (range, 20–68 mm Hg), the fraction of inspired oxygen was 0.6 (range, 0.3–1.0), and the PaO<sub>2</sub>/fraction of inspired oxygen was 150 (range, 73–372). The patients flown by the FMMS had a lower ETCO<sub>2</sub> at the beginning of the flight in comparison with the patients flown by the German Air Force (30 vs. 42 mm Hg,  $P < .001$ ); the other parameters did not differ between the 2 subgroups.

The Charlson Comorbidity Index describing comorbidity<sup>9</sup> was 1 (range, 0–6), but there was a significant difference in the patients flown by the FMMS versus the German Air Force (1 vs. 2,  $P < .001$ ). Thirty-two patients (55%) required catecholamines when they were initially handed over, 34 patients (59%) received volume-controlled ventilation, and 24 patients (41%) received pressure-controlled ventilation.

The median transport-in-air time was 1 hour 10 minutes (range, 52 minutes–2 hours 5 minutes), and the median treatment time (transport time) was 2 hours 56 minutes (range, 1 hour 20 minutes–7 hours 30 minutes). The TAT index was 0.41 (range, 0.26–0.81). There was no significant difference for transport and transport-in-air times between the 2 subgroups (patients transported by the FMMS and the German Air Force), but the flight levels of the AE were significantly different (all German AEs were flown in 20,000 ft and all French AEs were flown in 30,000 ft, which is equivalent to a cabin altitude of 2,380 ft vs. 4,900–8,800 ft,  $P < .001$ ). One patient died during the first 7 days after flight (4%).

**Table 2**

A comparison of patient demographics between transport team origin, median (interquartile range) are shown, significance level is set to adjusted  $p^* < 0.0025$  for 20 parameters (highlighted in bold). FMMS = French Military Medical Service.

	Total	FMMS	German Air Force	P Value <sup>a</sup>
Number	58	36	22	
Sex, n (%)				
Male	40 (69)	24 (67)	16 (73)	.628
Female	18 (31)	12 (33)	6 (27)	
Age (years)	61.5 (12.8)	64.0 (14.0)	57.5 (12.0)	.009
BMI (kg/m <sup>2</sup> )	27.8 (5.2)	28.8 (6.5)	27.7 (4.0)	.150
Flight level (ft)	30,000 (10,000)	30,000 (0)	20,000 (0)	<b>&lt;.001</b>
Transport time (h:min)	2:56 (1:07)	3:05 (0:53)	2:47 (1:41)	.255
Transport-in-air time (h:min)	1:10 (0:10)	1:11 (0:13)	1:10 (0:20)	.627
TAT index <sup>b</sup>	0.41 (0.18)	0.40 (0.15)	0.49 (0.53)	.060
Preexisting conditions, n (%)				
In total	35 (61)	22 (61)	13 (59)	.879
Diabetes	16 (28)	12 (33)	4 (18)	.210
Hypertension	20 (35)	16 (45)	4 (18)	.041
Days of ventilation before flight	5 (7)	4 (3)	10 (10)	<b>&lt;.001</b>
Circulatory condition, n (%)				
Without catecholamines	26 (45)	12 (33)	14 (64)	.024
With catecholamines	32 (55)	24 (67)	8 (36)	
Heart rate (beats/min)	85 (25)	87 (26)	84 (25)	.868
Types of ventilation, n (%)				
Volume controlled	34 (59)	34 (94)	0 (0)	<b>&lt;.001</b>
Pressure controlled	24 (41)	2 (6)	22 (100)	
SaO <sub>2</sub> (%)	96 (6)	96 (6)	98 (7)	.655
ETCO <sub>2</sub> (mm Hg)	33 (11)	30 (7)	42 (23)	<b>&lt;.001</b>
FiO <sub>2</sub>	0.6 (0.3)	0.6 (0.2)	0.7 (0.2)	.057
PaO <sub>2</sub> /FiO <sub>2</sub>	150 (77)	143 (72)	166 (157)	.571
PEEP (cm H <sub>2</sub> O)	13.0 (2.0)	13.0 (2.0)	14.0 (7.0)	.661
Accordance with ARDS				
Network Table, n (%)	58 (100)	36 (100)	22 (100)	
Charlson Comorbidity Index	1 (3)	1 (2)	3 (1)	<b>&lt;.001</b>
Outcome on day 7 after flight, n (%)				
Alive	57 (98)	36 (100)	21 (96)	.197
Death	1 (2)	1 (4)	1 (4)	

ARDS = acute respiratory distress syndrome; BMI = body mass index; ETCO<sub>2</sub> = end-tidal carbon dioxide; FiO<sub>2</sub> = fraction of inspired oxygen; FMMS = French Military Medical Service; PEEP = positive end-expiratory pressure.

<sup>a</sup> The significance level is set to adjusted  $P < .0025$  for 20 parameters.

<sup>b</sup> The ratio between the transport time and transport-in-air time is the TAT index.

## Discussion

This analysis of AE flights conducted by the French and German Air Force is 1 of the first to present data on the AE of critically ill, intubated patients during the current COVID-19 pandemic. The presented analysis will help to understand the challenge for the medical crew during the flight, to improve the processes for the transportation of COVID-19 patients during this pandemic, and to optimize decisions on the selection of suitable patients for transportation.

Although acute respiratory distress syndrome is not a rare condition, data on the air transport of such patients are limited. In an assessment of American AE flights between November 2005 and March 2007, Dorlac et al<sup>10</sup> identified only 5 flights in which patients with significant pulmonary impairment were accompanied by specially trained teams with intensive care ventilators, although during the same period mechanically ventilated patients with other primary diseases or injuries were transported more frequently. For example, from October 2001 to May 2006, 1,265 mechanically ventilated trauma patients were evacuated by the United States Air Force out of Iraq and Afghanistan. The patients transported had suffered poly-trauma responsible for severe injuries possibly associated with acute respiratory distress syndrome.<sup>11</sup> Barillo et al<sup>12</sup> published positive data on pressure-controlled ventilation for the air medical transport of patients with burns. For this reason, lessons learned in these studies have only limited application to the current COVID-19 pandemic and similar diseases. Ponsin et al<sup>13</sup> also published the data of 16 years of French military experience of AE with an intensive care practitioner on board. They reported the AE of 453 patients, with 150 of them mechanically ventilated.

For COVID-19 patients, there are only a few studies available.<sup>14,15</sup> The analysis with the largest number of patients (N = 385) from Hilbert-Carius et al<sup>14</sup> analyzed 385 COVID-19 transports, mainly on primary missions performed by ground vehicles and for interfacility transport by helicopters. Patients on primary missions were less sick than interfacility transport patients for whom air transport was the preferred method. According to the publication from Albrecht et al<sup>15</sup> and their experience with COVID-19 air transport, there are some recommendations for helicopter<sup>16</sup> and fixed wing transportation.<sup>17,18</sup> These recommendations were based on experience with the transportation of patients with other infectious diseases or with only fewer COVID-19 patients at a time. In total, our analysis increased the scientific available data for the transportation of COVID-19 patients.

In our analysis, the patients flown by FMMS and the German Air Force exhibited few clinically relevant differences. The main differences were operational parameters in flight, such as flight level, or in some cases medical treatment, such as the ventilation mode. These differences were the results of individual medical decisions, whereas the patient's current status before AE were also different. One of the main pre-AE differences with regard to medical management was the delay before performing AE. The French patients were flown earlier (3 vs. 10 days after initiating mechanical ventilation). The earliest transfer of patients shortly after initiating mechanical ventilation has the inherent advantage of making intensive care beds available for other patients. Incidentally, the Charlson Comorbidity Index was lower in patients transported by the FMMS. However, it should be kept in mind that the Italian patients were selected by the local authorities and not by the flight surgeon, whereas the French Air Force selected the patients on the basis of strict criteria.<sup>19</sup>

This analysis shows that the transportation of COVID-19–infected, ventilated patients is an enormous challenge with the need of intensive care during transportation before, during, and after the flight. Every patient suffered from COVID-19 and required intensive care for some time. Avoiding the saturation of intensive care units is 1 of the key challenges, at least from a system perspective in managing COVID-19 patients. The potential gain in the availability of intensive care beds is a cornerstone of this management, and this gain is much

higher if the transportation is done at the beginning of the intensive care treatment.

In comparison with a group of COVID-19 patients at a university hospital in Germany who all had preexisting conditions,<sup>20</sup> the patient group analyzed here appears healthier. However, this could be explained by the fact that not all patients had a doctor's referral and thus the intensive care transport team was not aware of all preexisting conditions but also because the patients were highly selected before their transportation out of the group of patients susceptible for transfer.

Given the intensive care interventions that were necessary to prepare the patients for AE and to stabilize them during the flight (including deepening anesthesia and treating circulatory instability), the number of patients per intensive care team must not be exceeded (no more than 2 patients per team). Medical teams need to be well trained and need appropriate intensive care equipment, especially in regard to the medical and technical problems they may face during the transport of intensive care patients.<sup>7,21–23</sup> This is particularly important when interhospital transports of COVID-19 patients are required to relieve hospitals with many COVID-19 patients to hospitals with more capacity for the treatment of a COVID-19 patient collective or when other transfers of mechanically ventilated intensive care patients are useful. However, at the same time, the need for intensive care teams to accompany patient transport will reduce the number of doctors and nurses available in hospitals, especially if patient transfers are not performed in a proactive manner (ie, in stable situations) but rather, as in Italy and France, only once the health care system is already overwhelmed.

The transport time was short at 1 hour 10 minutes, but it should also be noted that our analysis only covers the time between the handover of the patient by the civilian emergency service and the handover at the destination airport. Thereafter, patients had to be carried by air or ground to the destination hospital. Our analysis of transport times shows that the handover times of these critically ill patients constitute a significant part of the overall treatment time. The TAT index is less than 0.50, which means that the flight time was less than 50% of the overall treatment time. The reason for this is on the one hand the complexity of the disease, which requires uncompressible time for the transfer of such intensive care patients, and on the other hand the flight distances in central Europe are quite short. The low value of the TAT index suggests that the periods of handovers, embarking, and disembarking are crucial, and the relative importance of the flight itself is probably not as high. We identify these periods as the main targets of training programs. In addition to rest periods for flight and medical crewmembers, longer ground stops for loading and unloading also affect the supplies of medicine and, in particular, transportable oxygen. This must be taken into consideration when planning missions and when choosing the means of transport, especially for shorter distances when ground-based transport is an alternative for patient transport within 1 country.

In addition, the frequent disconnections from ventilators (intensive care ward, ground transport, air transport, air/ground transport, and destination hospital) along with changes in ventilation equipment may be detrimental for the continuity of ventilation. Incidents relating to the intrahospital transport of critically ill patients and adverse health outcomes have been described in the literature.<sup>24,25</sup> Additional unfavorable circumstances for the ventilation status of patients include inadequately equipped ground vehicles for transport from the initial hospital to the aircraft and in some cases a long ride from the aircraft to the destination hospital.<sup>26</sup> For future decisions on AE flights for COVID-19 patients, the total circumstances should always be considered and compared with alternative transportation methods by ground vehicles, helicopters, or trains.

Our analysis has several limitations. Although this is the largest analysis of fixed wing–transported COVID-19 patients, the group of

examined patients is small with only 58 patients. Although the primary disease and the flight conditions were comparable, a larger group would have been helpful for further analyses. Even though all transported patients were included in our study, the selection of patients was made by national authorities before transport or by the flight surgeon; for this reason, we were only able to conduct a descriptive analysis of the available medical data. Furthermore, we were only able to analyze the data that had been provided in patient movement requests and available medical records and that had been collected during transport. The quality and quantity of documentation clearly must be optimized, in particular with regard to readability and the completeness of patient histories. This was likely due to circumstances surrounding patient handover. We were able to find missing data from other sources (Patient Movement Request, doctor's letters, and flight records), especially for preexisting medical conditions, transport times, and so on.

In summary, this analysis of the first 58 COVID-19 transports from Italy and France provides important initial findings on the status of such patients, the number and type of intensive care personnel needed (intensive care doctors and specialist nurses), and the necessary parameters for mission planning and execution. In addition to these findings, further data must be collected over the course of the COVID-19 pandemic and for similar future incidents and should be used in planning the transfer of COVID-19 patients.

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