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Original Research

Descriptive Analysis of Coronavirus Disease 2019 Air Medical Evacuations by Critical Care Air Transport Teams

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A B S T R A C T

Objective: Preserving air medical evacuation capabilities for critically ill patients with coronavirus disease 2019 (COVID-19) required innovation for en route care logistics, training, and equipment. The aim of this study was to describe characteristics and in-flight interventions for patients with suspected COVID-19 requiring air medical evacuation by US Air Force critical care air transport teams (CCATTs).
Methods: We performed a retrospective chart review of patients with suspected COVID-19 requiring air medical evacuation by CCATT from April 2020 to February 2021. We included patients with an available CCATT medical record and transport with COVID-19 infection isolation precautions. CCATT medical records were the data source, and we performed descriptive analyses of patient characteristics and in-flight interventions.
Results: We reviewed 460 records and identified 16 patients for inclusion. The Transport Isolation System (50%) and Negatively Pressurized Conex (31%) were commonly used portable biocontainment units. The median patient age was 48.5 years, and 94% were male. All patients required oxygen supplementation, with 8 (50%) receiving mechanical ventilation. In-flight interventions among intubated patients (n = 8) included vasopressors (50%), paralytics (25%), and patient-ventilator asynchrony management (63%).
Conclusion: Patients with COVID-19 requiring CCATT transport were older than prior military en route care cohorts, and in-flight interventions for patient-ventilator asynchrony were commonly required during mechanical ventilation.

The world is currently experiencing a pandemic caused by a novel coronavirus, severe acute respiratory syndrome coronavirus 2, which leads to the disease referred to as coronavirus disease 2019 (COVID-19). The clinical presentation ranges from no symptoms to fever, cough, dyspnea, expectoration, headache, myalgia, and fatigue and in 5% to 20% of patients progresses to critical illness primarily characterized by acute respiratory distress syndrome.[1] The pandemic is having a significant impact on the Military Health System, affecting 72,671 active duty service members as of 10 December 2020, plus an additional 36,167 Military Health System beneficiaries.[2] Approximately 9% of these cases occurred outside of the continental United States.[2] An article published in the December 2020 Medical Surveillance Report described 225 air evacuations of COVID-19–infected service members in the Central Command (n = 186) and European Command (n = 39) areas of responsibility.[3] The report had limited clinical data and did not describe critically ill patients.

US Air Force critical care air transport teams (CCATTs) are 3-person teams composed of a physician, nurse, and respiratory therapist with the mission of transporting critically ill patients within and out of theaters of combat operations to higher levels of care.[4,5] CCATT also assists in natural disasters, humanitarian efforts, and medical evacuations for US military personnel across the globe. The COVID-19

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Figure 1. A Negatively Pressurized Conex. The top photograph shows a Negatively Pressurized Conex being loaded onto a C-17 Globemaster III (https://www.af.mil/News/Article-Display/Article/2517264/negative-for-covid-19/). The bottom photograph shows the interior of a Negatively Pressurized Conex (https://usdefensestory.com/new-kid-on-the-block-negatively-pressurized-conex-npc-arrives-at-ramstein/).

pandemic challenged the en route care community to transport large volumes of patients with effective infection isolation precautions during flight. In response to this need, the Air Force developed the Negatively Pressurized Conex and the Negatively Pressurized Conex-Lite to provide airborne isolation precautions during flight (Fig. 1).[6] COVID-19 transports were augmented with a public health official and infectious disease specialist to assist with adherence to infection isolation precautions and protocols for enplaning, in-flight care, and deplaning.[2] These personnel work closely with air medical evacuation crews who manage noncritically ill patients requiring air transport. Portable biocontainment units were a requirement for regulated transports of patients with confirmed or suspected COVID-19 in order to reduce risk of in-flight disease transmission to aircrew, medical personnel, and other passengers. Civilian transport services made similar efforts to augment critical care and infection isolation capabilities for interfacility transports of critically ill patients with COVID-19.[7,8]

The aim of this study was to describe characteristics and in-flight interventions for patients with COVID-19 requiring air medical evacuation by CCATT. Describing critically ill patients with COVID-19 and resources used for air medical evacuation will help inform planning and delivery of future en route care for COVID-19 and other highly contagious diseases. It is imperative that we record lessons learned from the current pandemic to be better prepared to respond to future threats and preserve en route care capabilities while mitigating spread of infectious disease. The description of epidemiologic parameters of COVID-19 is important in the provision of critical information to inform modelers and policy makers.

Methods

We performed a retrospective analysis of patients requiring transport by US Air Force CCATT with concern for COVID-19 between March 2020 and February 2021. The US Air Force 59th Medical Wing Institutional Review Board approved this study.

We queried the En Route Critical Care Pilot Unit Quality Improvement database for CCATT transport missions for patients with COVID-19. After receipt of potentially eligible patients, we searched the Theater Medical Data Store (TMDS) for CCATT medical records. For patients with CCATT medical records, the patient movement record from TRANSCOM Regulating and Command & Control Evacuation System and the CCATT medical record, Air Force Form 3899 (Appendix Figure 1), were reviewed. The inclusion criteria included 1) transport by CCATT, 2) an available CCATT medical record, and 3) COVID diagnosis or suspicion necessitating infection isolation precautions for transport. We excluded patients with no available CCATT medical record.

Data Sources

Trained research nurses with experience in CCATT medical records abstracted patient demographics, clinical characteristics, and in-flight events into an Access database (Microsoft Corporation, Redmond, WA). Demographic data included age, sex, and service status. Clinical characteristics included documented past medical history related to an increased risk for severe COVID-19 illness, the presence and method of COVID-19 diagnosis, and COVID-19 treatment preflight. Preflight and in-flight respiratory support characteristics were collected for each patient. The type of isolation system (if any) and in-flight pain and sedation doses were recorded.

All data recorded were based on documentation in the patient movement record or provider documentation in the 3899 form. Usual data quality measures, to include meetings between the principal investigator and abstractors to develop abstraction guidelines, regular discussions to clarify unclear entries, and quality assurance checking by a second team member, were used. The principal investigator

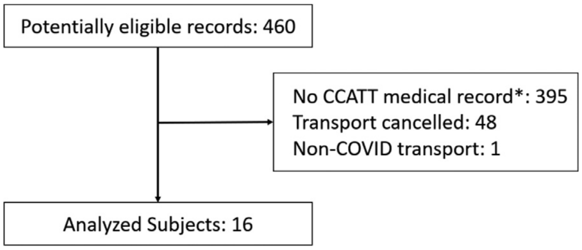

Figure 2. The Consolidated Standards of Reporting Trials flow diagram. *CCATT medical records were only generated for critically ill patients primarily assigned to CCATT for in-flight care.

reviewed the free-text narrative of each record to provide a narrative summary of any in-flight events or COVID-19 management decisions.

Statistical Analysis

Descriptive analyses were performed for all data. Given the limited number of patients meeting the enrollment criteria, we calculated frequencies with percentages and medians with ranges or interquartile ranges for the majority of data elements.

Results

We reviewed 460 records from TMDS. The most common reasons for exclusion were lack of a 3899 CCATT medical record and canceled transports (Fig. 2). The initial search contained missions with CCATT augmentation for infection isolation precautions, but CCATT medical records were generated only for critically ill patients primarily assigned to CCATT. Thus, the high proportion of patients without a CCATT medical record was likely due to many patients requiring air transport with infection precautions but not being critically ill enough to require primary assignment to CCATT. We identified and analyzed 16 patients meeting the inclusion criteria.

The median age was 48.5 years, and most patients (94%) were male (Table 1). Diabetes (19%) was the most common comorbidity, but the majority of patients (63%) had no documented pre-existing medical conditions associated with an increased risk for severe COVID-19 illness. The majority of patients had positive COVID-19 polymerase chain reaction testing, but specific numbers are not currently approved for information release. Preflight fever (69%) was common.

Aircraft platforms included the C-17 (94%) and C-130J (6%). The median transport time was 7.3 hours (range, 0.7-17 hours). The Transport Isolation System was the most commonly used portable biocontainment unit (50% of flights) followed by the Negatively Pressurized Conex (31%). All patients required oxygen supplementation in-flight, with 50% receiving mechanical ventilation (Table 2). All patients (N = 16) received deep vein thrombosis prophylaxis. Among intubated patients (n = 8), in-flight interventions included vasopressor (63%) and paralytic (25%) administration. All intubated patients received continuous fentanyl and propofol infusions, with 25% of intubated patients also receiving ketamine infusions. Three patients required additional intravenous pushes of analgosedation in-flight (Table 3). Patient-ventilator asynchrony (PVA) was documented in 63% of patients requiring mechanical ventilation. Four of 5 patients with PVA were successfully managed with a ketamine intravenous push. The fifth patient required increasing levels of sedation and the initiation of chemical paralysis to enable tolerance of mechanical ventilation.

Notable findings from a narrative case review included in-flight chest pain in 1 patient with a preflight pulmonary embolus diagnosis (Table 4). In-flight awake prone positioning was successfully implemented in 1 nonintubated patient with a high preflight oxygen requirement. One intubated patient had worsening respiratory status in-flight requiring up-titration of mechanical ventilation to 100% fraction of inspired oxygen and the initiation of chemical paralysis. One transport team successfully performed a flight line transfer of care from a stretcher to a litter at the back of the aircraft while maintaining infection isolation precautions for a critically ill patient with multiple tubes, lines, and drains.

Table 1
Demographics and Preflight Coronavirus Disease 2019 Diagnosis and Treatments

	Analyzed Patients (n = 16)
Origin	
Middle East	14 (87.5)
Europe	1 (6.3)
Asia	1 (6.3)
Destination	
Middle East	1 (6.3)
Europe	14 (87.5)
United States	1 (6.3)
Age, years	48.5 (38.8-55)
Male	15 (93.8)
Days since symptom onset	8 (4-11)
Past medical history[a]	
Diabetes	3 (18.8)
Hypertension	2 (12.5)
Smoking	1 (6.3)
Precedence category	
Urgent	4 (25)
Priority	11 (68.8)
Routine	1 (6.3)
Portable biocontainment unit	
TIS	8 (50.0)
NPC	5 (31.3)
NPCL	1 (6.3)
Unknown	2 (12.5)
Preflight medications	
Antiviral agent	5 (31.3)
Corticosteroid	10 (62.5)
Antibiotic	12 (75.0)

NPC = Negatively Pressurized Conex; NPCL = Negatively Pressurized Conex Lite; TIS = Transport Isolation System.
Data are presented as median (interquartile range) or frequency (percentage).
[a] No patients had documented pre-existing cardiac (other than hypertension), pulmonary, kidney, liver, or neurologic conditions.

Table 2
Respiratory Characteristics Among Intubated and Nonintubated Patients

	Nonintubated (n = 8)
Preflight	
Supplemental O_2, L/min	4 (1-6)
O_2 saturation, %	96 (93-97)
In-flight	
Supplemental O_2, L/min	4 (1-8)
Minimum O_2 saturation, %	92 (85-93)
	Intubated (n = 8)
Preflight	
O_2 saturation, %	96 (93.5-96)
PaO2 : FiO2	159 (131-184)
Mechanical ventilation	
FiO_2, %	60 (55-70)
Respiratory rate	14 (13-17)
Tidal volume	450 (450-480)
PEEP	10 (5-10)
In-flight	
Minimum O_2 saturation, %	93.5 (92.3-94.0)
Minimum P/F ratio	146 (104-155)
Maximum required ventilation settings	
FiO_2, %	60 (52.5-90)
Respiratory rate	22 (16.8-24)
Tidal volume	490 (450-540)
PEEP	10 (5.8-13.5)

All data are presented as median (interquartile range).
FIO_2 = fraction of inspired oxygen; PEEP = positive end-expiratory pressure; PaO2 : FiO2= arterial oxyen partial pressure to fraction of inspired oxygen.

Table 3
In-flight Analgosedation Dosing for Ventilated Patients (n = 8)

	Fentanyl	Propofol	Ketamine
IV infusion administered	8 (100)	8 (100)	2 (25)
IV infusion dose	100 μg/h (75-500)	43 μg/kg/min (20-60)	18.5 μg/kg/min (17-20)
IV push administered	1 (12.5)	3 (37.5)	2 (25)
IV pushes per transport	2	3 (1-3)	6 (5-7)
IV push dose	37.5 μg (25-50)	20 mg (10-40)	100 mg (100-150)

IV = intravenous.
All data are presented as frequency (percentage of ventilated patients) or median (range).

Table 4
A Narrative Summary of Select Cases

Narrative Case Descriptions
1. Nonintubated patient with concomitant pulmonary embolism developed chest pain during flight with associated ST depressions. Pain resolved spontaneously, and electrocardiography improved postflight.
2. Nonintubated patient with preflight oxygen saturation of 87% on 6 L/min was transitioned to awake prone positioning. He tolerated in-flight prone positioning for 3 hours and had an increased oxygen requirement to 8 L/min after transition to supine positioning.
3. Intubated patient with high preflight sedation requirement required in-flight initiation of chemical paralysis and an increase of ventilation support to 100% fraction of inspired oxygen and positive end-expiratory pressure of 14 cm H_2O.
4. Intubated patient with 5 medication drips required flight line transfer of care on flight line from wheeled stretcher to medical litter.
5. Point-of-care ultrasound was used in flight to guide fluid management after 1 patient developed hypoxia and tachycardia during flight.
6. Patient ventilator asynchrony was successfully managed with ketamine IVP in 4 patients. One patient required push dose phenylephrine for transient hypotension.
7. Hyperglycemia was managed with insulin.

IVP = .

Discussion

The COVID-19 pandemic challenged the US military en route care system to enable air transport of US personnel across the globe while maintaining infection isolation precautions to limit COVD-19 transmission risk to aircrew and health care workers. This study highlights the retention of en route critical care capabilities with the transition of the care environment from an open bay to portable biocontainment units with enhanced personal protective equipment for infection isolation precautions. Among patients with concern for COVID-19 requiring critical care during transport, essential medical capabilities include mechanical ventilation with increased positive end-expiratory pressure and hemodynamic monitoring and medication pumps to enable simultaneous infusions of analgosedation.

A cohort of interfacility transports in civilian systems found that 40% of patients required mechanical ventilation, 32% required vasopressor support, and 80% required oxygen therapy. In this cohort, 13% received neuromuscular paralysis before transport, and another 5% of patients had chemical paralysis initiated during transport.[9] Although our study had a very limited sample size, patients in the military en route critical care system required interventions with similar frequency to this civilian cohort. PVA was frequently documented during flight, and most teams successfully used ketamine boluses to resolve these episodes.

Self-proning in nonintubated patients with COVID-19 has been previously described to assist with oxygenation.[10,11] Self-proning was feasible for a portion of air transport for a single patient in the current cohort. Given the long transport times and vibrations of military aircraft, transport teams should consider that patients will not be able to tolerate self-proning for the entirety of a transport.

As noted in Table 4, 1 case required transferring a fully loaded critical care patient to a different litter on the flight line at the back of the aircraft. Prior case series have noted the importance of a CCATT capability to be able to safely transition and package patients in a variety of operational conditions to include flight line transfers.[12] CCATT teams performing COVID-19 transports receive additional training to transition usual en route critical care skills to the infection isolation environment to include a portable biocontainment unit and additional personal protective equipment. The successful and safe transfer of this patient represents a successful validation of these training efforts. Retention of these skills as COVID-19 transports decline for CCATT will be a future challenge for skill sustainment training platforms.

Limitations

Limitations of our study include a lack of data regarding COVID-19 transmission among medical crew and aircrew performing these evacuations, but military publications have suggested that transport using these precautions is safe.[6] We lack clinical outcomes for these patients after transport, but flight care records indicated that the patients were transferred to definitive care in stable condition. The small sample size as a result of this very specialized population of air transport patients does not allow for inferential statistics. CCATTs were part of an augmentation package for COVID-19 transports, but we were only able to include patients with a CCATT medical record in TMDS. This may result in missing some COVID-19 patients who received en route critical care from CCATT.

Conclusions

Patients with COVID-19 requiring CCATT transport were older than prior military en route care cohorts, and in-flight interventions for PVA were commonly required for patients receiving mechanical ventilation.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2021.09.005.

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