Feasibility of Lung Point-of-Care Ultrasound for Patients With COVID-19 in Air Medical Transport: Triage of 2 Initially Suspected Cases on Mexico’s Front Line

To the Editor: The aeromedical transport of patients in a critical condition, both in the rotary and fixed wings, is a challenge for health personnel and an unmatched advantage for the transported patient, shortening the transport time from the scene to the receiving hospital or between hospitals to one with higher capacities. We report the use of lung point-of-care ultrasound (POCUS) in 2 suspected cases of coronavirus disease 2019 (COVID-19) and how the use of a pulmonary triage system based on lesion characteristics was useful to increase suspicions of the disease and determine air transport to a hospital at the start of the pandemic in Mexico.

A highly trained aeromedical crew can improve the diagnosis and treatment of critically ill patients with respiratory distress when the place of arrival does not have the necessary diagnostic or therapeutic capacities and can follow up on the treatment provided by an intensive care unit, taking the aircraft as an extension of the emergency department and intensive care unit in the air for these purposes. However, there are immediate disadvantages involved in airlifting a patient with an infectious disease such as COVID-19, which pose great challenges and potential threats to the crew, making aeromedical transports more complicated than they already are.

So far, there have been very few publications addressing aeromedical transport during this COVID-19 pandemic, and most have focused on the precautions required for isolation of the aircraft, patients, and crew members,1–3 which is the main disadvantage of the transport of confirmed or suspected patients during the pandemic. The routine use POCUS currently functions as an auxiliary tool that has become particularly interesting and useful during the pandemic4 because of the multiple advantages it has over lung auscultation5 and chest radiography,6 allowing the selective request of computed tomographic scans, particularly in children and pregnant women,7 prehospital or in-hospital triage of patients,8 the possibility of being performed at the bedside with pocket devices,9 the speeding up of diagnoses, and modifications of established treatments for invaluable savings of economic resources.10

Severe Acute Respiratory Syndrome Coronavirus 2–Related Injuries Found by Ultrasound

To date, worldwide, the lesions identified by pulmonary ultrasound (US) in COVID-19–positive patients seem to correlate with our findings in Mexico that these are pleural line irregularities (thickening or complete rupture), subpleural consolidations without a bronchogram and areas of white lung, and vertical artifacts (rare and isolated or multiple). These lesions are characterized by a typical “patchy” and bilateral distribution, several areas of preserved tissue mixed with diseased tissue, and some typical images of interstitial alveolar damage and diminished local blood flow observed by Doppler imaging, particularly in symptomatic patients.8 All of these findings have also been reported as preliminary findings in children.11

Methods

Lung POCUS Before Triage for Respiratory Distress During the COVID-19 Pandemic

For these cases, informed consent of the patients included was obtained, as well as the approval of the Institutional Review Board of the Latin American Institute of Ultrasound in Mexico. The arrival of the epidemic in rural areas, with deficiencies of resources and oversaturated urban medical services without the capacity to care for critically ill patients, requires rapid priority mobilization10; therefore once the aeromedical crew that will attend to the emergency is notified of COVID-19, it will request the patient’s respiratory status and the corresponding POCUS lung triage during the preflight medical evaluation according to previous publications8,10,12,13. On arrival at the scene, the medical crew will confirm or reclassify the status of the lung injury as follows:

- Green: normal lung, pattern A—dry lung, presence of A-lines, pleural sliding, presence of power Doppler findings, and a lung ultrasound (LUS) score of 0 in most lung areas or 1 in some areas. These patients are at low risk and can be monitored at home.
- Yellow: wet lung, pattern B—2 or 3 B-lines, diminished pleural sliding, mild pulmonary edema, regular to slightly irregular pleura, and an LUS score of 1 in most areas (those with an irregular and indented
pleural line with vertical artifacts) or 2 in some areas (broken pleural line, pattern of subpleural consolidation, and patchy areas of white lung). These patients have a moderate risk and should be evaluated in the hospital, unless accurate and frequent home medical services can be guaranteed.

- Red: wet lung, pattern B—more than 4 B-lines, moderate to severe alveolar damage, interstitial pulmonary edema, an irregular pleural line, an interrupted image, presence of white lung or subpleural consolidations, and an LUS score of 2 or 3 in most areas. These patients are at high risk and should be quickly evaluated in the hospital and admitted.

This system allows professionals to determine the severity at the prehospital preflight stage, during flight, and at the postflight stage due to the acknowledgment of any suggestive imaging that is highly suspicious of severity. With portable or pocket devices, the examination allows a real-time reassessment of the condition of the ill onboard the aircraft, reducing time and costs, avoiding unnecessary radiographs, and allowing the selective request of computed tomography. The POCUS scan has the versatility of being reproduced as many times as necessary with immediate results, having the opportunity to change the triage color at the moment: reclassifying the severity or improvement of the disease. This POCUS triage can help professionals pick out low-risk (green) cases at first contact, which can lead to considering them “negative by LUS,” testing of the patient, and isolation of the patient; those “suggestive or positive by LUS” (yellow and red) with abnormal patterns ought to be evaluated in the emergency department. The use of remotely controlled pocket equipment (via Bluetooth or WiFi) is recommended, since phones, transducers, and tablets ought to be covered. All electromedical devices, including transducers and pocket/portable devices, must be covered to minimize their exposure. This can be accomplished by using protective bags or plastic wraps, which must be decontaminated before delivery to the receiving hospital and before their final destination at the aeromedical base.14

**Point-of-Care US Insonation by Medic Crew Members**

If the patient is sitting during the preflight phase, the thorax will be explored from 3 different views (anterior, lateral, and posterior) and in 7 different segments by hemithorax according to Soldati et al18:

anterior, superior and inferior; lateral, superior and inferior; and posterior, superior, middle, and inferior.

These are 14 segments in total. The sweep will be performed from median to lateral and downward, placing the transducer both transversely and longitudinally, with one mark pointing to the head and a medial position. The findings should be registered according to the segment and the intercostal space in which they were found.

If the patient is in the supine or prone decubitus position at any time during the transport, the thorax is limited to 2 views, depending on the patient’s position: anterior, superior and inferior segments; and posterior, superior, middle, and inferior segments. Lateral sides can be explored as well: superior and inferior. Decline zones should always be explored.

**Notification of the Hospital Center**

Personnel must notify the hospital of the patient’s condition, as is regularly done, stressing the patient’s lung and respiratory conditions. They can reclassify the respiratory status according to the lung injuries found and institute some treatment before boarding the aircraft. During the flight, the lung status can be monitored, as is usually done with the electromedical equipment. Once the receiving hospital has been notified and with prior knowledge of pulmonary triage and the established treatment, health workers at the receiving hospital will be able to adequately prepare for careful reception of the patient and ensure the best available treatment. Likewise, US telemonitoring can be implemented by an expert when the flight’s medical personnel have doubts about the images they are capturing, and they can receive advice and avoid errors in difficult cases at the point of care.

**Report of 2 Cases With Dyspnea During the Start of the COVID-19 Pandemic in Mexico**

We describe 2 cases of dyspnea that were initially suspected of being COVID-19, in which a US scan was performed at the point of care by medical crew members, which helped determine the initial treatment and etiology and accelerated notification of the receiving hospital center about the state of the patients thanks to the US findings.
Case 1
Preflight Medical Evaluation
An 80-year-old male patient had a history of travel to Germany and Spain in February 2020. His symptoms included dyspnea of medium effort, coldlike symptoms accompanied by fever of 38°C, myalgia, runny nose, retro-ocular pain, headache, a history of poor arterial hypertension that was controlled, and newly

Figure 1. A. Posterior thorax, upper regions of both lungs, dry lung, presence of pleural sliding, 2 vertical artifacts (asterisk), and correlation with M-mode imaging. B. Posterior thorax, middle regions, vertical artifacts, no more than 3 B-lines (asterisks), and regular pleural line. M-mode imaging shows loss of lung aeration. C. Posterior thorax, basal lower regions, and correlation with bilateral pleural effusion (PE). These are not the COVID-19–related injuries reported to date, despite being a suspected patient with dyspnea and a history of contact at the start of the pandemic in Mexico.
diagnosed Kidney Disease Improving Global Outcomes stage G4 chronic kidney disease. Vital signs were oxygen saturation of 80% in ambient air, blood pressure of 150/100 mm Hg, heart rate of 100 beats per minute, and respiratory rate of 23 breaths per minute. At a private hospital, oxygen therapy was started with a simple mask at 10 L/min; a peripheral venous line was established; and electromedical monitoring was performed. On arrival of the medical crew members, an extended thoracic US scan was performed.

Figure 2. Echocardiography. A, Apical 4-chamber window shows right ventricular and atrial enlargement. B, During the lung exploration, we noticed an anechoic area (asterisk) in the anterior thorax suggestive of pericardial effusion. C, Enlargement of the right ventricle, with a right ventricle-to-left ventricle ratio of greater than 1.0. D, Positive McConnell sign with confirmed pericardial effusion in the short-axis view. LA indicates left atrium; LV, left ventricle; RA, right atrium; and RV, right ventricle.
performed at the point of care. The patient was suspected of having COVID-19 by the operational definition at the time of the pandemic. (Operational definitions changed with the course of the pandemic.)

**Point-of-Care LUS Findings**
- Anterior thorax with the presence of pleural sliding identified by power Doppler imaging in both hemithoraxes together with fewer than 3 vertical...

**Figure 3.** A. Left posterior thorax LUS in the upper region shows dry lung and presence of A-lines. B. Left posterior thorax LUS in the middle region. Although A-lines (asterisks) can still be seen, the pleural irregularity begins to become evident, with vertical artifacts below the rupture. C. Right posterior thorax LUS in the upper region shows dry lung and presence of A-lines. D. Right posterior thorax LUS in the middle region shows pleural irregularity with multiple vertical artifacts and 2 intercostal spaces below. E. Increased pleural irregularity with multiple areas of loss of aeration and a small consolidation showing patchy areas of white lung. F. Subcostal echocardiography does not show dilatation of cavities or pericardial effusion. Liv indicates liver.
artifacts. The pleural line was regularly identified without interruptions or thickenings. In lower portions, there was a loss of pleural sliding due to a subpleural anechoic image, consistent with bilateral pleural effusion with echoes inside and the jellyfish sign in the right hemithorax. The lung POCUS score was 0.

- Posterior thorax with the presence of pleural sliding and A-lines in the upper portions of both

Figure 4. A, Transverse rotation of the transducer of Figure 3E increased the artifacts, making evident the pleural irregularity and an anechoic image (asterisk) related to pleural effusion. B and C, Right posterior thorax (B) and left posterior thorax (C) in basal regions. There is bilateral pleural effusion (asterisks), a broken pleural line (shred sign), subpleural consolidations with multiple vertical artifacts, patchy areas of the lung, and lateral views. D and E, Same pattern of injury, which seemed to respect the integrity of the diaphragm. Liv indicates liver.
hemithoraxes, a middle region with the presence of fewer than 3 vertical artifacts, a pleural line without thickening, irregularities, or ruptures, and lower basal portions with an anechoic image corresponding to bilateral pleural effusion. The lung POCUS score was 0 (Figure 1).

- On echocardiography, the 4-chamber window revealed dilatation of the right ventricle and left atrium, and a short-axis view at the level of the papillary muscles revealed a positive McConnell sign and a right ventricle-to-left ventricle ratio of greater than 1. The images corresponded to dilated cardiomyopathy (Figure 2).

A green negative POCUS lung triage for COVID-19 was established (not presenting suggestive images caused by severe acute respiratory syndrome coronavirus 2 [SARS-CoV-2]). The air transport to his city of origin was made for definitive treatment as a low-risk patient for COVID-19. He was treated during the flight with 7-L nasal-tip oxygen therapy, an N95 mask, the semi-Fowler position, and continuous electromedical monitoring. The staff carried level III personal protective equipment for aerosol-generating procedures. The patient’s condition was considered a congestive heart failure exacerbated by mild respiratory disease; the laboratory test for SARS-CoV-2 was given 5 days after the transport, yielding a negative result.

Case 2
Preflight Medical Evaluation
A 55-year-old female patient with no history of travel attended a public hospital with limited resources for dyspnea of medium effort, fever of 38.5°C, a nonproductive intermittent cough, lower and lateral chest pain, holocranial headache of 8 to 10, and a history of hypertension and diabetes without other comorbidities or chronic disease. Vital signs were oxygen saturation of 80% in ambient air (88%–90% with 5-L nasal-tip oxygen therapy), blood pressure of 130/75 mm Hg, heart rate of 105 beats per minute, and respiratory rate of 25 breaths per minute. She was given 1 g of intravenous paracetamol every 8 hours. She had an initial chest radiograph that showed an increase in bronchovascular marks 3 days previously. On arrival of the medical crew members, an extended thoracic US scan was performed at the point of care at the time of transport, pending a confirmatory result for SARS-CoV-2.

Point-of-Care LUS Findings
- Anterior thorax with the presence of A-lines, pleural sliding present in both hemithoraxes, a pleural irregularity without thickening or rupture, an inferior region with interruption and irregularity of the pleural line, and confluent vertical artifacts without subpleural consolidations. The lung POCUS score was 0 to 1.
- Posterior thorax with the presence of a normal lung, A-lines, pleural sliding present, a middle region with pleural irregularity, more than 3 confluent vertical artifacts in some sites, and no patchy areas of white lung (Figure 3, A–D), a lower region with patchy areas of white lung, pleural rupture

![Image](image-url)
with multiple small subpleural consolidations below each ruptured area in both hemithoraxes in both lower basal regions, and a small pleural effusion located in the posterior lower areas. The lung POCUS score was 2 to 3 (Figure 4).

- On echocardiography, a 4-chamber subcostal image was obtained, which did not reveal a pericardial effusion or dilatation of the atrial/ventricular cavities. The 4-chamber, long-axis, and short-axis images were of poor quality and were not considered for the evaluation (Figure 3F).

A red POCUS lung triage was established for COVID-19 with the worst lung POCUS score of 2 to 3 in the basal fields. This patient was considered highly suspicious of having COVID-19, with US images compatible with those of SARS-CoV-2 infection and consistent with those reported in the literature. The air transport was made to an urban hospital center 200 km away with more capabilities due to the progression of the disease and high suspicion of COVID-19, where the diagnosis was confirmed by the laboratory. The transport was conducted with nasal tips at 5 L/min (maintaining saturations at 92%–93%), an N95 mask, and a face shield. The crew carried level III personal protective equipment for aerosol-generating procedures.

**Take-Home Message for Air Medicine**

Up to now, no critically ill patient with COVID-19 undergoing mechanical ventilation or other aerosol-generating procedures has been transported by our center because of the risk that this entails for the medical crew onboard, such as limited space that facilitates fomites and airborne droplet transmission, the lack of complete isolation cabinets for the patient, and the difficulty of disinfecting the helicopter. There is no standardized program for the aeromedical transport of patients with infectious diseases, such as the US Army Medical Response Institute of Infectious Diseases (Air Aeromedical Isolation Team) established in 1970, a program that has developed isolation cabins specially designed for the containment of highly contagious diseases such as ebola. The lack of such a program makes it difficult to routinely use a rotary wing for transportation during the pandemic. The availability of aircrafts exclusively for this medical purpose is quite rare in this country; most are multipurpose helicopters that have been reconverted for medical care (Figure 5).

All of these strategies could work better and be more viable in fixed-wing aeromedical transport because of the greater ease of isolation. The patient’s clinical severity must be taken into account, and physiologic adaptations during flight are likely to worsen the patient’s hemodynamic condition; therefore, a higher altitude and longer flight time will make a transport more complicated. The important factors that must be considered are not currently addressed, which is one of the reasons why these transports have no longer been prioritized, preferring ground ambulances.

However, in both cases described here, the lung POCUS during the pandemic was very helpful, since the ultrasound before the flight, during the flight, and at the time of delivery to the receiving hospital seems to be viable in ideal conditions of isolation and should be part of the guidelines for air transports that derive from the experiences of this pandemic as it was in 2004. The characteristics of SARS-CoV-2 represent a challenge that requires the development of better strategies to minimize the exposure of aeromedical crew members; however, our cases may set a precedent for future research.
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