Lung ultrasound monitoring of CPAP effectiveness on SARS-CoV-2 pneumonia: A case report

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Abstract

SARS-CoV-2 infection is characterized by extremely heterogeneous features, going from cases with few symptoms to severe respiratory failures. Chest Computed Tomography (CT) is currently the gold-standard imaging method, although burdened by the risk of exposure to ionizing radiation and management / organizational concerns. In particular, the critical patient undergoing ventilation (invasive or not) seems to be difficult to monitor by repeated CT scan over time. We report the case of a 55-year-old male patient subjected to Continuous Positive Airway Pressure (CPAP) and prone positioning, in which the use of ultrasound monitoring allowed to verify the effectiveness of the pressure support used in recruiting previously atelectasis lung areas. Lung ultrasound can guide pulmonary recruitment and pronation maneuvers in patients undergoing non-invasive ventilation. Ultrasound can identify atelectatic lung areas, which demonstrate an alveolar re-expansion following the setting of high PEEP values, as underlined by the reappearance of pleural/air interface.

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Introduction

The SARS-CoV-2 pandemic has surprisingly brought to light the role of lung ultrasound.[1,2] Covid-19 infection is characterized by extremely heterogeneous features, going from cases with few symptoms to severe respiratory insufficiencies and fatal complications.[3-5] Chest Computed Tomography (CT) is currently the gold-standard imaging method offering the best diagnostic accuracy, although burdened by the risk of exposure to ionizing radiation and management / organizational concerns.[6] In particular, the critical patient undergoing ventilation (invasive or not) seems to be difficult to monitor by repeated CT scan over time. Lung ultrasound is a bed-side, simple, low cost and repeatable method.[1,2] Some reports in literature reported that awake early proning in the emergency department induces improved oxygen saturation in Covid-19 patients.[7,8] We report the case of a 55-year-old male patient hospitalized in a critical setting and subjected to Continuous Positive Airway Pressure (CPAP) and prone position, in which the use of ultrasound monitoring allowed to verify the effectiveness of the pressure support used in recruiting previously atelectasis lung areas.

Case Report

A 55-year-old male patient was transferred to our unit from a spoke hospital for worsening respiratory failure treated with conventional oxygen therapy. The patient had been hospitalized for the onset of dyspnea, fever and cough from about 10 days. His past medical history was characterized by hypertension treated with valsartan/ hydrochlorothiazide, first degree obesity. In the medical history, there were no pulmonary disease and no tobacco consumption. The patient weighed 94 kg and was 173 cm tall. Blood exams revealed: white blood cells: 10.29 x10^9/L (4.00 - 10.00), hemoglobin 13.3 g/dL (13.5 - 17.0), neutrophils 9.10 x 10^9/L (2.00 - 8.00), lymphocytes 0.74 x 10^9/L (1.00 - 4.00), D-dimer 813 ug/L (Cut-off VTE exclusion<500), creatinine 0.64 mg/dL (0.70 - 1.20), AST 251 U/L (< 40), ALT 349 U/L (< 41), LDH 950 U/L (135 – 225), C-reactive protein 2,2 mg/L (< 5.0), high-sensitivity-troponin 9 ng/L (99th percentile: 15 ng/L), procalcitonin 0.9 ug/L (<0,5 low risk of sepsis), IL-6 20.7 pg/ml (< 5.9), PT/INR 1.33 (0.8 – 1.2). Blood cultures were negative for bacterial and fungal growth.

Bilateral parenchymal consolidations were present on the chest X-ray, more evident in the upper lobes, minimal bilateral pleural effusion and normal cardio-mediastinal shadow. A SARS-CoV-2 positive swab was performed. On the same day, he carried out infectious disease advice recommending antiviral therapy with darunavir 800 mg 1 cp OD and ritonavir 100 mg 1 cp OD and hydroxychloroquine 200 mg 1 cp BD. Furthermore, dexamethasone (20 mg OD) and low molecular weight heparin (LMWH) (6000 UI OD) therapy was undertaken. Then, the patient was transferred to our emergency medicine ward for clinical worsening. Vital parameters were: Respiratory Rate (RR) 30 acts/min, cardiac rate 100 bpm, blood pressure 140/70 mmHg, peripheral oxygen saturation 94% on conventional oxygen therapy 15 liter/min (P/F = 100). Lung ultrasound performed during conventional oxygen therapy showed the presence of bilateral sub-pleural consolidations, with some lung fields characterized by coalescent B lines as for "white lung" (Figure 1); taking as reference the Lung Ultrasound Score9 exam scheme (Figure 2), the patient was given a value of 32.

In the emergency medicine ward, the patient was first treated with Ventimask (Fio2: 60%) reporting a P/F value of 115. Then, the patient was subjected to a protocol based on CPAP with helmet interface (StarMEd helmet interface) with flow 85 L/min (14 + 14), FiO2 57% and PEEP 12.5 cm H_2O. The patient was subsequently positioned in the prone position to obtain a further improvement in gas exchange. The improvement of the Arterial Blood Gas Analysis (ABG) data was highlighted after four hours (Table 1). In particular, the patient had an improvement of P/F (215), and a reduction of the RR of about 5 acts/min during pronation (see Table 1 for comparison). The therapeutic protocol required the patient to perform CPAP in the prone position during the day, and in the supine position during the night.

After two days of CPAP treatment and prone positioning, the consolidative areas disappeared and was documented the presence of areas with non-coalescent B lines and even lung fields with pattern A; the LUS score was 4 (Figure 3). The alveolar gas exchanges always remained constant over time of CPAP therapy. The patient performed the CPAP and pronation protocol for 5 days. The possibility of continuous assistance from the staff and the good compliance of the patient did not require the use of sedative therapies to perform CPAP.

Discussion

SARS-Cov-2 can induce pneumocytic damage directly and generate an inflammatory response leading to an accumulation of inflammatory fluid that occupies the interstitium and progressively the alveolus; that induces a progressive loss of air which is progressively replaced by cellular / inflammatory material.[5,10] On lung ultrasound, the progressive loss of alveolar aeration is manifested by the passage from a pleural air interface with A lines (horizontal artifacts) to one with B lines (vertical artifacts), which gradually increase in number and become coalescent (white lung).[2,11-14] Previous data demonstrated a correspondence between the ultrasound finding of white lung and that of ground-glass on chest CT.[1,2] In the most severely affected areas, the total loss of alveolar air manifests on ultrasound with a solid pattern, thus showing lung consolidations, with the presence of any aerial bronchograms. Moreover, in the critically ill patient with severe hypoxemia and alteration of the respiratory drive, areas of atelectasis due to basal fields disventilation may occur, due to diaphragmatic hypomobility, thus leading to worsening of the clinical picture[15,16]

This process of progressive alveolar de-aeration finds a reverse confirmation through to the use of ventilation methods. In our case, a CPAP therapy with prone positioning was used, that allowed the re-ventilation of atelectasis areas through the application of positive pressure.[17] In pneumonia, CPAP was used mainly for non-hypercapnic acute respiratory failure.[18-20] On ultrasound, the process of re-ventilation is evidenced by the progressive disappearance of the consolidation areas, in favor of an air interface, with a gradual reduction in the number of B lines, up to a normal A pattern. Therefore, lung ultrasound allows to monitor the effect

Figure 1. Lung ultrasound on conventional oxygen therapy: bilateral subpleural consolidations, with some lung fields characterized by coalescent B lines as for "white lung".

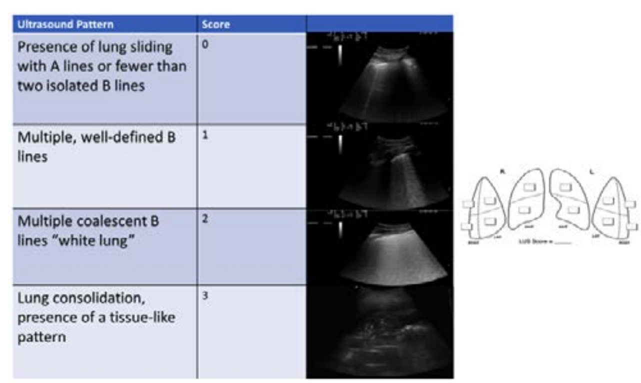

Figure 2. Ultrasound scan was taken in six regions for each lung (superior and inferior areas in the anterior, lateral, and posterior fields using anterior and posterior axillary lines as landmarks). Four ultrasound aeration patterns were defined in each region: presence of lung sliding with A lines or fewer than two isolated B lines (0); multiple, well-defined B lines (1); multiple coalescent B lines or white lung (2); lung consolidation (3). LUS scores were calculated as the sum of all.

Table 1. ABG values and Respiratory Rate (RR) in the different phases of oxygen therapy and non-invasive ventilation.

	pH	pO_2 (mmHg)	pCO2 (mmHg)	P/F	FiO_2 (%)	RR (acts/min)
Ventimask	7,53	69,3	28	115	60%	36
CPAP	7,47	80	26	140	57%	33
CPAP + prone position	7,48	123	32	215	57%	28

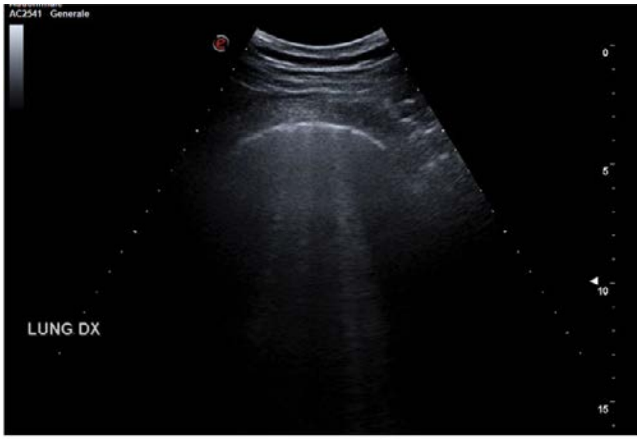

Figure 3. Lung ultrasound after CPAP: non-coalescent B lines and even lung fields with pattern A.

of applying a ventilation method (positive pressure) on specific lung areas, scanned in a serial way. Furthermore, the verification of the success of the attempt to re-expand atelectasis lung areas allows to set the pressure values employed by CPAP more precisely. In our case, pronation maneuver was also performed, thus leading to good results even with non-invasive ventilation.

In our opinion, the improvement of pulmonary compromise, as demonstrated by ultrasound, is due to CPAP and pronation therapy rather than to a healing process of the pathology, since the time elapsed between the two checks (2 days) is too much short, and in this period of time no specific therapies were included.

Conclusions

It is possible to monitor SARS-CoV-2 pneumonia evolution by ultrasound through a seriated evaluation of signs of pulmonary disease (B lines reduction / increase or appearance / disappearance of the consolidations and atelectasis) by adopting an ultrasound execution scheme. Lung ultrasound can guide pulmonary recruitment and pronation maneuvers in patients undergoing invasive ventilation; indeed, ultrasound can identify atelectatic lung areas, which demonstrate an alveolar re-expansion following the setting of high PEEP values, as underlined by the reappearance of pleural air interface.

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