Critically ill patients with COVID-19 in Hong Kong: a multicentre retrospective observational cohort study

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ABSTRACT

Objective: To report the first eight cases of critically ill patients with coronavirus disease 2019 (COVID-19) in Hong Kong, describing the treatments and supportive care they received and their 28-day outcomes.

Design: Multicentre retrospective observational cohort study.

Setting: Three multidisciplinary intensive care units (ICUs) in Hong Kong.

Participants: All adult critically ill patients with confirmed COVID-19 admitted to ICUs in Hong Kong between 22 January and 11 February 2020.

Main outcome measure: 28-day mortality.

Results: Eight out of 49 patients with COVID-19 (16%) were admitted to Hong Kong ICUs during the study period. The median age was 64.5 years (range, 42–70) with a median admission Sequential Organ Failure Assessment (SOFA) score of 6 (IQR, 4–7). Six patients (75%) required mechanical ventilation, six patients (75%) required vasopressors and two (25%) required renal replacement therapy. None of the patients required prone ventilation, nitric oxide or extracorporeal membrane oxygenation. The median times to shock reversal and extubation were 9 and 11 days respectively. At 28 days, one patient (12%) had died and the remaining seven (88%) all survived to ICU discharge. Only one of the survivors (14%) still required oxygen at 28 days.

Conclusion: Critically ill patients with COVID-19 often require a moderate duration of mechanical ventilation and vasopressor support. Most of these patients recover and survive to ICU discharge with supportive care using lung protective ventilation strategies, avoiding excess fluids, screening and treating bacterial co-infection, and with timely intubation. Lower rather than upper respiratory tract viral burden correlates with clinical severity of illness.

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The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the cause of the 2019 novel coronavirus disease (COVID-19).[1] Data from the Wuhan epicentre in China show that 23–32% of hospitalised patients required intensive care unit (ICU) admission.[1-3] Furthermore, the 28-day mortality in a cohort of ICU patients with COVID-19 was 61.5%.[4] In particular, 81% of those requiring either invasive or non-invasive ventilation (NIV) died within 28 days of ICU admission. However, given that the sheer number of patients in Wuhan exceeded the capacity of existing ICUs, the data may not be representative of outcomes in less strained health care systems. Detailed information focused specifically on critically ill patients with COVID-19 outside the Hubei province is currently limited. This information is needed to inform critical care surge planning and management of patients with COVID-19.[5] We report data from a Hong Kong cohort of critically ill patients with COVID-19, describing their organ dysfunction, treatments and 28-day outcomes.

Methods

Study design and cases

We conducted a multicentre retrospective observational cohort study of all adult critically ill patients with confirmed COVID-19 admitted to ICUs in Hong Kong between 22 January and 11 February 2020. All patients had positive real-time reverse transcriptase polymerase chain reaction to SARS-CoV-2 in their respiratory specimens. The study reports a retrospective analysis of data collected prospectively for submission to the World Health Organization clinical characterisation database. The last follow-up day was 9 March 2020. Data on the total number of patients with confirmed COVID-19 in Hong Kong were obtained from the Centre for Health Protection. This study was performed in accordance to the Declaration of Helsinki. It was approved by the Joint Chinese University of Hong Kong–New

Territories East Cluster Clinical Research Ethics Committee (2020.059 and 2020.076) and local ethics committees at each participating hospital.

Participating intensive care units

The three participating institutions in Hong Kong were Prince of Wales Hospital, Princess Margaret Hospital and Pamela Youde Nethersole Eastern Hospital. Princess Margaret Hospital is a designated infectious disease hospital, Prince of Wales Hospital is a tertiary teaching hospital and Pamela Youde Nethersole Eastern Hospital is an acute district general hospital. All three have multidisciplinary ICUs accredited by the College of Intensive Care Medicine of Australia and New Zealand and are staffed with critical care specialists and nurses capable of providing extracorporeal membrane oxygenation (ECMO). The nursing to patient ratios across the three ICUs are at least 1:1 during dayshift and 1:2 during nightshift. The Acute Physiology and Chronic Health Evaluation (APACHE) IV standardised mortality ratios of the three ICUs in 2019 were between 0.65 and 0.7. The patients were all cared for in single airborne infectious isolation rooms. The personal protective equipment for health care workers consisted of a disposable gown, a face shield, gloves, cap, and fitted N95 respirator. Patients with COVID-19 were not treated with NIV or high flow nasal oxygen (HFNO) due to concerns with infectious risks.

Data collection

We collected demographic, epidemiological, clinical, treatment and outcome data with standardised data collection forms shared by WHO. Additional ICU-specific data such as daily fluid balance and vasopressor dosage were collected. We followed up patients until 28 days after ICU admission to report their outcomes on duration of organ support, ICU and hospital discharge status, and survival.

Viral load quantification

We collected serial nasopharyngeal and tracheal specimens for viral load quantification from patients admitted to the Prince of Wales Hospital's ICU. Samples were stored in viral transport medium, and viral RNA was extracted using the PureLink Viral RNA/DNA Mini Kit (Invitrogen, USA). SARS-CoV-2 was quantified by real-time reverse transcriptase polymerase chain reaction, with primers and probes targeting the N gene of SARS-CoV-2.[6] The lower viral detection limit was 2.84 log copies/mL. The viral load results presented have not been previously published but will be incorporated in the analysis of a virology study including patients with all spectrum of COVID-19 severity.

Statistical analysis

Descriptive statistics such as frequencies and percentages were used for categorical variables, while continuous variables were expressed as mean with standard deviation (SD) or median and interquartile range (IQR). SPSS version 24 (IBM) was used for all statistical analysis.

Results

Demographics and characteristics

Forty-nine patients with confirmed COVID-19 were identified in Hong Kong during our study period. Of these, eight (16%) were admitted to the ICU. Demographic, clinical characteristics and baseline laboratory results of the patients admitted to the ICU are shown in Table 1. The median time between hospital and ICU admission was 3 days (IQR, 1–5 days). Three patients had comorbidities including hypertension, diabetes and chronic renal impairment but none had chronic lung disease. None of the patients had positive bacterial or fungal cultures within the first 2 days of ICU admission. All of the patients received empirical antibiotics, most commonly ceftriaxone (38%), piperacillin/tazobactam (25%), and meropenem (25%). Only two patients had positive bacterial growth after 48 hours of ICU admission. One patient had *Serratia* in tracheal aspirate on Day 4 of ICU care. The other patient had *Enterobacter* in sputum on Day 12 of ICU admission (2 days after extubation). Lopinavir and ritonavir were given to all patients and 75% (6/8) received the combination within 48 hours of hospital admission. Ribavirin was given to all patients except two patients who developed renal impairment. Half of the patients received corticosteroids (one patient received a total methylprednisolone 750 mg and the others received up to 300 mg of hydrocortisone daily) while other immunomodulatory agents such as intravenous immunoglobulin (1/8), interferon-β (2/8), and montelukast (2/8) were given infrequently. The median time to defervescence from symptom onset was 17 days (IQR, 13–26 days).

Organ dysfunction and support

The laboratory results and daily Sequential Organ Failure Assessment (SOFA) scores for the first 7 days of ICU are shown in Table 2. All ventilated patients fulfilled the Berlin definition of acute respiratory distress syndrome (ARDS).[7] We were unable to determine whether the remaining two patients had ARDS because we did not use NIV. The lowest arterial partial pressure of oxygen (Pao_2) to fraction of inspired oxygen (Fio_2) ratio was 102 mmHg and the highest dose of norepinephrine was 1.9 μg/kg/min. Six

Table 1. Demographics and characteristics

	Values
Total number of patients	8
Age (years), median (range)	64.5 (42–70)
Weight (kg), median (IQR)	70 (52–74)
Female sex	4 (50%)
Hypertension	3 (38%)
Diabetes	2 (25%)
Cardiovascular disease	0 (0%)
Chronic renal impairment	2 (25%)
Chronic obstructive pulmonary disease	0 (0%)
Asthma	0 (0%)
Malignancy	0 (0%)
Chronic liver disease	0 (0%)
Alcohol	2 (25%)
Smoking	1 (13%)
Travel history outside of Hong Kong	5 (63%)
Signs and symptoms	
Fever	8 (100%)
Cough	6 (75%)
Rhinorrhoea	0 (0%)
Myalgia or fatigue	5 (63%)
Sputum	5 (63%)
Headache	0 (0%)
Diarrhoea	2 (25%)
Abdominal pain	1 (13%)
Dyspnoea	8 (100%)
Days from symptoms to hospital admission, median (IQR)	7 (4–10)
Days from symptoms to ICU admission, median (IQR)	10 (9–11)
Days from symptoms to mechanical ventilation, median (IQR)	10 (9–11)
Bilateral infiltrates on chest x-ray	8 (100%)
APACHE II score, median (IQR)	12.5 (9–16)
Laboratory results on admission, median (IQR)	
Haemoglobin (g/dL)	12.8 (11.9–14.2)
White cell count ($\times 10^9$/L)	6.6 (3.42–11.7)
Neutrophils ($\times 10^9$/L)	5.2 (2.3–10.6)
Lymphocytes ($\times 10^9$/L)	0.7 (0.5–1.0)
Platelet ($\times 10^9$/L)	154 (127–241)
PT (s)	13 (12.4–13.4)
INR	1.1 (1.1–1.2)
APTT (s)	35.6 (33.4–39.0)
Creatine kinase (U/L)	115 (64–160)
Lactate dehydrogenase (U/L)	329 (266–507)
Bilirubin (μmol/L)	6 (5–8)
ALT (IU/L)	28 (20–45)
Urea (mmol/L)	3.4 (2.5–7.9)
Creatinine (μmol/L)	70 (56–110)
CRP (mg/L)	194 (72.9–284)
Procalcitonin (ng/mL)	0.2 (< 0.05–0.2)

ALT = alanine transaminase; APACHE = Acute Physiology and Chronic Health Evaluation; APTT = activated partial thromboplastin time; CRP = C-reactive protein; INR = international normalised ratio; IQR = interquartile range; PT = prothrombin time.

patients (75%) required mechanical ventilation and all of them were intubated on the first day of ICU admission. Muscle relaxants were used in 83% (5/6) of patients on mechanical ventilation. Low tidal volume lung protective ventilation strategy (mean, 6.4 mL/kg; SD, 0.6 mL/kg) was used for patients ventilated for ARDS during controlled ventilation modes. Six patients (75%) required vasopressor for septic shock while two (25%) required renal replacement therapy. None of the patients required prone ventilation, nitric oxide or ECMO.

Clinical outcomes

At 28 days after ICU admission, one patient (12%) had died and the seven survivors (88%) had been discharged from the ICU (Table 3). Median times to shock reversal and extubation were 9 and 11 days respectively. None of the patients had pneumothorax. Among the survivors, only one (14%) had been discharged from hospital at Day 28. At 28 days, one of the survivors (14%) still required supplementary oxygen. Other reasons why patients remained in hospital include rehabilitation, need for dialysis and completion of antibiotics. The total COVID-19 patient-days in the ICU was 89, and there was no reported nosocomial transmission of SARS-CoV-2.

Respiratory viral loads

The viral copies from two patients who received invasive mechanical ventilation are shown in Table 4. Viral copies in tracheal aspirates were consistently higher than in the nasopharynx and only peaked after invasive mechanical ventilation was required.

Discussion

In this multicentre ICU cohort (16% of total COVID-19 cases in Hong Kong), one of the eight patients (12%) died and all survivors were discharged from the ICU by 28 days. In the two patients from whom we obtained respiratory viral loads, upper respiratory tract viral burden did not reflect the viral loads in lower respiratory tract samples. We found that 75% of patients required mechanical ventilation and vasopressor therapy, but none required prone ventilation or ECMO.

These findings are substantially different to those reported from Wuhan, where 23–32% of patients required ICU admission and mortality was substantially higher (38–61.5%).[1-4] More recent data from ICUs in Kirkland and Seattle, United States, also suggest high COVID-19-related ICU mortality of at least 50–67%.[8,9]

The reasons for the difference in ICU admission rate are not immediately clear, but may reflect differences

Table 2. Laboratory results and organ function during first week in the intensive care unit (ICU)

	Laboratory results						
Laboratory tests	**Day 1 ICU**	**Day 2 ICU**	**Day 3 ICU**	**Day 4 ICU**	**Day 5 ICU**	**Day 6 ICU**	**Day 7 ICU**
Haemoglobin (g/dL)	12.5 (11.9–13.7)	11.8 (10.5–13.4)	11.6 (10.8–13.2)	10.6 (10.3–13.7)	10.5 (9.7–13.1)	9.6 (9.5–13.2)	10.5 (10.5–13.3)
White cell count (× 10^9/L)	8.3 (4.6–12.5)	7.5 (5.5–9.0)	7.8 (5.6–10.7)	8.0 (5.4–9.8)	7.4 (6.5–12.0)	7.4 (5.8–14.5)	10.5 (6.2–17.9)
Neutrophil (× 10^9/L)	7.3 (3.4–11.4)	4.4 (5.8–7.7)	6.2 (4.1–9.5)	6.8 (3.9–8.0)	6.2 (4.9–9.9)	6.2 (5.0–12.3)	9.1 (5.3–15.6)
Lymphocyte (× 10^9/L)	0.6 (0.5–.85)	0.8 (0.6–1.1)	0.9 (0.4–1.3)	0.9 (0.7–1.2)	0.9 (0.7–1.5)	0.9 (0.5–1.2)	1.1 (0.4–1.4)
Platelet (× 10^9/L)	227 (189–239)	228 (202–275)	232 (193–311)	245 (205–351)	275 (211–351)	269 (194–343)	273 (236–390)
PT (s)	12.4 (12.1–13.4)	12.7 (12.1–13.1)	13.3 (11.9–13.7)	12.4 (11.7–12.6)	12.8 (12.1–13.7)	13.1 (12.8–14.3)	13.4 (12.8–15.6)
APTT (s)	33.7 (33.1–34.8)	34.1 (32.4–37.9)	36.9 (32.3–45.7)	33.8 (31.2–38.8)	34.4 (31.7–37.1)	35.8 (33.7–38.5)	34.1 (32.8–40.4)
INR	1.1 (1.1–1.2)	1.1 (1.1–1.2)	1.2 (1.1–1.2)	1.1 (1.1–1.2)	1.2 (1.1–1.2)	1.2 (1.2–1.2)	1.2 (1.1–1.3)
Creatine kinase (U/L)	97 (33–179)	66 (31–141)	105 (24–436)	120 (15–534)	240 (37–882)	242 (38–1502)*	137 (106–813)*
Lactate dehydrogenase (U/L)	406 (336–678)	445 (324–593)	427 (304–563)	363 (270–444)	366 (227–489)	368 (250–407)	347 (255–397)
Bilirubin (μmol/L)	11 (7–20)	11 (8–19)	18 (17–20)	18 (10–31)	21 (16–37)	39 (17–103)	61 (30–150)
ALT (IU/L)	45 (33–62)	51 (34–79)	44 (36–83)	42 (33–74)	50 (36–88)	62 (33–93)	68 (28–77)
Urea (mmol/L)	5.6 (4.7–8.5)	7.0 (4.6–9.7)	10.9 (3.7–12.3)	10.3 (8.1–13.3)	9.6 (8.8–15.0)	9.4 (6.5–12.8)	7.5 (6.9–12)
Creatinine (μmol/L)	63 (46–110)	72 (55–163)	61 (49–252)	66 (55–243)	68 (49–250)	76 (49–254)	78 (49–236)
CRP (mg/L)	93–340*	80–350*	10–243*	na	na	na	na
Procalcitonin (ng/mL)	0.08–1.49*	na	0.11–0.29*	10.36–27.96*	< 0.05–26.33*	0.22–6.45*	0.57–2.8*
Lactate (mmol/L)	1.1 (1.0–1.9)	1.3 (1.1–1.7)	1.7 (1.0–2.3)	1.7 (1.4–2.0)	1.8 (1.5–2.3)	2.4 (1.4–2.7)	2.1 (1.7–6.1)
Organ function							
Pao_2/Fio_2 ratio (mmHg)	183 (144–237)	187 (154–212)	200 (141–244)	211 (155–346)	216 (154–302)	191 (157–212)	150 (121–311)
Norepinephrine (μg/kg/min)	0.01 (0–0.07)	0.06 (0.01–0.10)	0.5 (0.01–0.19)	0.04 (0.01–.13)	0.05 (0.00–0.12)	0.05 (0.00–0.13)	0.03 (0.00–0.07)
Fluid balance (mL/day)	–152 to 789*	–285 (–731 to 564)	630 (72–1612)	974 (–249 to 1382)	227 (–381 to 335)	302 (–593 to 736)	–205 (–521 to 739)
SOFA score	6 (4–7)	7 (4–8)	7 (4–9)	7 (3–9)	8 (3–10)	9 (6–12)	8 (6–12)

ALT = alanine transaminase; APTT = activated partial thromboplastin time; CRP = C-reactive protein; Fio_2 = fraction of inspired oxygen; INR = international normalised ratio; na = not applicable; Pao_2 = arterial partial pressure of oxygen; PT = prothrombin time; SOFA = Sequential Organ Failure Assessment. All values are expressed as median (interquartile range) unless otherwise specified.
* Range.

Table 3. Outcomes at 28 days after admission to the intensive care unit (ICU)

ICU resource use	Values
Days on vasopressor, median (IQR)	9 (8–12)
Days on invasive mechanical ventilation, median (IQR)	11 (9–15)
Patient-centred outcomes	
ICU mortality	1/8 (12%)
Survival to ICU discharge	7/8 (88%)
ICU length of stay in survivors (days), median (IQR)	12 (8–16)
Hospital mortality	1/8 (12%)
Hospital discharge in ICU survivors	1/7 (14%)
Free from oxygen supplement	6/7 (86%)

IQR = interquartile range.

in accessibility to diagnostic testing and hospital bed availability. It is possible that a greater proportion of patients in Hong Kong with relatively minor disease were admitted to hospital for isolation after laboratory confirmation. This would result in an increase in the denominator. In contrast, 93% of non-ICU patients admitted to hospital in Wuhan required supplementary oxygen.[1] This suggests that their hospitalised patients with COVID-19 had more severe disease and may explain their higher ICU admission rates.

Similarly, there are insufficient directly comparative data to fully explain the differences in patient outcomes. Possible explanations include differences in severity of illness, supportive therapy, casemix, use of antivirals, and ICU resources. Our patient who died was the oldest patient in our cohort and had multiple comorbidities, including incompletely treated pulmonary tuberculosis. He developed progressive severe lactatemia, and computed tomography showed an incidental aortic dissection. Although there was no definite ischaemic bowel on imaging, he developed progressive multi-organ failure and died. It is therefore not clear if his death was directly related to the SARS-CoV-2 infection.

Our median APACHE II score was lower than the median score in Wuhan (12.5 *v* 17); however, the median SOFA score of 6 (IQR, 4–7) was comparable to the SOFA score of non-survivors in Wuhan (median, 6; IQR 4–8) and higher than survivors (median, 4; IQR 3–4).[4] The severity of illness in the Kirkland and Seattle cohorts was not reported.[8,9] Our cohort (median age, 64.5 years; range, 42–70 years) was generally older than cohorts admitted to ICUs in Wuhan but younger than those reported from Kirkland and similar to those in Seattle.[1-4,8,9] Comorbidity was common in all cohorts but, in the absence of objective measures of comorbidity severity, casemix variability remains a possible important contributor to the differences in outcome. We did not use HFNO nor NIV, whereas both were commonly used in Wuhan.[3,4] It is likely, therefore, that our invasively ventilated patients had less severe respiratory failure than those in Yang and colleagues' cohort.[4] Certainly, the high mortality — 86% dead, remaining 14% still ventilated at Day 28 — among invasively ventilated patients in that cohort would suggest that they had very severe respiratory failure. Another consideration is whether the use of HFNO and NIV in Yang et al's cohort[4] resulted in delayed intubation. The median ICU admission Pao_2/Fio_2 ratio in non-survivors was 62.3 mmHg (IQR, 52.0–74.1 mmHg), but 50% of these patients were treated with HFNO, 72% were supported by NIV, and only 59% received invasive mechanical ventilation. Compared with data from the United States, similar rates of mechanical ventilation (71–75%) were needed for critically ill patients with COVID-19. The median admission Pao_2/Fio_2 ratios in the Seattle and Kirkland cohorts were lower at 142 mmHg (IQR, 94–177 mmHg) and 169 mmHg (IQR, 69–492 mmHg) respectively, compared with our median Pao_2/Fio_2 ratio of 183 mmHg (IQR, 144–237 mmHg), but the difference was small.[8,9]

Another reason for our cohort's lower mortality could be the early and consistent use of antivirals in our patients. All of our patients were given lopinavir and ritonavir. Most of them received antivirals within 48 hours of hospital admission. In contrast, only 44–93% of patients received

Table 4. Serial nasopharyngeal and tracheal viral loads

		2 Days before intubation	Day of intubation	2 Days after intubation	1 Week after intubation
Patient A	Nasopharynx (log copy/mL)	6.80	5.99	6.84	3.51
	Tracheal aspirate (log copy/mL)	Na	7.30	7.31	4.62
Patient B	Nasopharynx (log copy/mL)	4.75	3.17	Negative	Negative
	Tracheal aspirate (log copy/mL)	na	6.33	6.70	5.26

The severe acute respiratory syndrome coronavirus (SARS-CoV-2) detection limit of real-time reverse transcriptase polymerase chain reaction was 2.84 log copies/mL.

antivirals in Wuhan.[2,4] It is not clear if the use of antivirals contributed to our lower ICU admission and mortality rates; however, a recent, underpowered placebo-controlled randomised controlled trial showed a trend toward improved outcome with lopinavir–ritonavir.[10] There are data showing that upper respiratory viral loads reach nadir at about Day 9 of illness, which coincides with time to ICU admission in our study, suggesting that severe disease is not due to overwhelming infection and antivirals may not change the outcome of critically ill patients.[11,12] However our data show that while nasopharynx SARS-CoV-2 viral load did not correlate with clinical deterioration, tracheal aspirate viral loads were persistently higher than nasopharyngeal viral loads. Furthermore, viral load in the lungs may continue to increase despite undetectable levels in the nasopharynx for patients with severe lung involvement. It remains possible that multi-organ failure in patients with COVID-19 may be due to uncontrolled viral infection in the lungs and consequent reactive inflammatory process. We speculate timely antivirals may rapidly reduce peak viral load early and mitigate the subsequent inflammatory response.

Perhaps most importantly, there may be substantial differences in the circumstances in which our ICUs and the Wuhan ICUs were functioning. Our ICUs were working within normal capacity. In contrast, two new hospitals were built in Wuhan within 10 days to help treat the overwhelming number of patients, suggesting that their health care system was likely under severe strain.[13] However, resource limitation is unlikely to fully explain the high mortality described from the first cohorts of critically ill patients with COVID-19 in the United States.[8,9]

The severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) epidemics were associated with a mortality of 34% and 74.2% in critically ill patients respectively.[14,15] Our data suggest that COVID-19 mortality rates in critically ill patients are lower compared with SARS and MERS. Although 75% of our cohort required mechanical ventilation, we did not observe barotrauma events, which were commonly seen in SARS.[14,16] Interestingly, the time between symptom onset and ICU admission was also about 10 days in SARS and MERS,[16,17] suggesting that there is a window of opportunity in which to treat with antivirals and immunomodulation to prevent coronavirus-induced multi-organ failure. Unfortunately, like the SARS and MERS epidemics, there is no proven effective specific treatment for COVID-19. Nevertheless, our data showed that standard supportive care with lung protective ventilation strategies, avoiding excess fluids, screening and treating bacterial co-infection, timely intubation and admission to critical care in patients with COVID-19 were associated with outcomes comparable or even better than patients with other causes of ARDS.[18] Furthermore, with rigorous infection control precautions across three different ICUs, none of our staff who reported symptoms suggestive of COVID-19 tested positive for SARS-CoV-2. However, we have not systematically looked for evidence of health care worker infection, and the possibility of asymptomatic infection cannot be excluded.

The major limitation of this study was the small sample size, which means our mortality rate is an imprecise estimate of the population mortality. The strength of the study was that we captured all patients with COVID-19 in Hong Kong requiring intensive care and none were lost to follow-up. Despite the limitations of the study, we feel our data are useful in demonstrating that outcomes are not necessarily poor when patients are treated in ICUs working within normal capacity. However, since critically ill patients with COVID-19 requiring invasive mechanical ventilation need a moderate duration of ventilator support, this may overwhelm even normally well resourced health care systems.

Conclusion

Critically ill patients with COVID-19 often require a moderate duration of mechanical ventilation and vasopressor support. Most of these patients recover and survive to ICU discharge with supportive care using lung protective ventilation strategies, avoiding excess fluids, screening and treating bacterial co-infection, and timely intubation. Lower rather than upper respiratory tract viral burden correlates with clinical severity of illness.

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Competing interests

None declared.

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