Title:

Clinical pathology of critical patient with novel coronavirus pneumonia (COVID-19)

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Summary

Background Novel coronavirus pneumonia (COVID-19) have emerged as major global health threats since December, 2019. Up to now, the histopathology of critical patient with COVID-19 remains largely undisclosed.

Methods We here performed the whole lung biopsy, and described the pathological changes of one COVID-19 critical patient done with transplant by HE staining, immunohistochemistry and special staining including Masson staining, PAS staining and silver methenamin staining.

Findings The whole lung tissue displayed diffuse congestive appearance or partly haemorrhagic necrosis on gross examination. The haemorrhagic necrosis was prominently present in outer edge of the right lobe of the right lung. The cut surfaces of the lung displayed severe congestive and haemorrhagic changes. The main pathological lung changes showed bronchiolitis and alveolitis with proliferation, atrophy, desquamation and squamous metaplasia of epithelial cells. Massive pulmonary interstitial fibrosis, and partly hyaline degeneration, variable degrees of hemorrhagic pulmonary infarction. Small vessels hyperplasia, vessel wall thickening, lumen stenosis, occlusion and microthrombosis formation. Focal monocytes, lymphocytes and plasma cells infiltrating into pulmonary interstitium. Atrophy, vacuolar degeneration, proliferation, desquamation and squamous metaplasia in alveolar epithelial cells. Alveolar cavity congestion was prominent, and contained mucus, edema fluid, desquamated epithelial cells, and inflammatory cells. We can also found several multinucleate giant cells and intracytoplasmic viral inclusion bodies. Masson staining indicated massive pulmonary interstitial fibrosis. Immunohistochemistry results showed positive for immunity cells including CD3, CD4, CD8, CD20, CD79a, CD5, CD38 and CD68.

Interpretation We show clinical pathology biopsy of critical patient with COVID-19, which might provide a deep insight of the pathogenesis and the severity of this disease.

Keywords   Novel coronavirus pneumonia; COVID-19; SARS-CoV-2; Pathology; Critical patient

Induction

The 2019 novel coronavirus pneumonia was officially named by the World Health Organization (WHO) as COVID-19. COVID-19 caused by SARS-CoV-2 was firstly emerged in December 2019, Wuhan city, and resulted in other cities including Shenzhen in China and other counties.[1,2] Reports regarding epidemiological and clinical characteristics of COVID-19 is accumulating.[3-5] Most of patients had fever and cough, and some patients developed acute respiratory failure, acute respiratory distress syndrome (ARDS), septic shock, and other severe complications. Different from other types of COVID-19, critical patients tend to have worse outcome and high mortality.[5] However, up to date, its clinical pathology remains largely unknown. Different from lung needle biopsy taken from the died patient recently reported by Wang FS research group,[6] we here performed the whole lung biopsy of the surgical patient, and for the first time, describe the main pathological changes of critical patient with COVID-19.

Methods

Patients and tissues

The 66-year-old patient had symptoms of high fever and cough when he came back to Shenzhen city from the Wuhan epidemic on January 4, 2020. He have no other basic diseases except 8-years-hypertension but with good cardiac function. The brightness of the right and left lungs were increased and multiple shadows were observed by chest x-ray. He was diagnosed as COVID-19 (critical type) and severe ARDS, and developed respiratory failure and was done with lung transplant. Informed consent was obtained.

Pathological tissues of the lung organ were collected in P3 laboratory, fix all tissues with 4% neutral buffered formaldehyde (pH = 7.0) for 24h. Dehydrate the fixed tissues in an ethanol series (100%, 95%, 80% and 75%) for 1 min in each percentage, clear in xylene and then embed in paraffin wax. Finally, cut the slices and incubate for 40 min in 70℃ oven. Special histochemical stains, for example, Masson staining was used to detect pulmonary interstitial fibrosis, periodic acid Schiff (PAS) staining and silver methenamin staining were used to identify bacterial and fungal infections. Masson kit (iron hematoxylin, bright red acid fuchsin working fluid, aniline blue, phosphomolybdic acid). Periodic acid Schiff and sliver methenamine kit (periodate, borax solution, silver nitrate hexamethylenetetramine powder).

Immunohistochemical stainin

The procedure of IHC was done as previously described.[7] In brief, paraffin-embedded sections were deparaffinized in xylenes for 20 min and rehydrated in an ethanol gradient. The sections were submerged into EDTA buffer and boiled for 2 mins with high-pressure for antigenic retrieval. After natural cooling, the slides were treated with 3% H_2O_2 to quench endogenous peroxidase activity, followed by incubation with 1% bovine serum albumin (BSA). The slides were incubated with the primary antibodies including CD3, CD20, CD79a, CD4, CD8, CD5, CD68, CD38, CD31, TTF1, CK5/6, CK7, CK19, SMA, F VIII and Collagen IV (working dilution, Zymed, San Francisco, CA) overnight at 4 °C. The sections were reacted with the biotinylated secondary antibody (Zymed, San Francisco, CA) and visualized with 3,3′-diaminobenzidine (DAB) under the microscopy.

Special staining

The tissues were fixed immediately in 10% formalin after dissection, paraffin-embed and

section at 1.5 µm thickness. The slices were deparaffinized in dimethylbenzene, oxidize the slices with 1% periodate for 30 min and rinse with distilled water. Immerse the sections into hexamine silver for 35 min (water bath 60 ℃). The sections were decolorized by 0.1% gold chloride (100 µl). Fix the tissues with 3% sodium thiosulfate for 1 min, replenish by the bouin's solution (37℃ water bath for 4 h) and wash the sections by distilled water for 5 min. The sections was dyed by Mayer hematoxylin and put into hot water (45℃) for 30 s. Stain the specimens by Masson solution (100 µl) for 30 min. Differentiate the sections by 1% phosphomolybdic acid (100µl). Remove phosphomolybdic acid and add the sections with 1% aniline blue (100 µl). Rinse the sections with distilled water, add 1% acetic acid. Dehydrate the sections lastly by 95% and 100% alcohol (10 s and 1 min, respectively) and seal.

Results

The surface of the whole lung was bronzing, and showed diffuse congestive appearance on gross examination (**Figure 1**). Most of them had punctate hemorrhage and partly haemorrhagic necrosis. Of note, the haemorrhagic necrosis was mainly present in outer edge of the right lower lobe, middle lobe and upper lobe of the lung. The bronchi were covered with mucinous and haemorrhagic exudation. The cut surfaces of the lung displayed severe congestive and haemorrhagic changes.
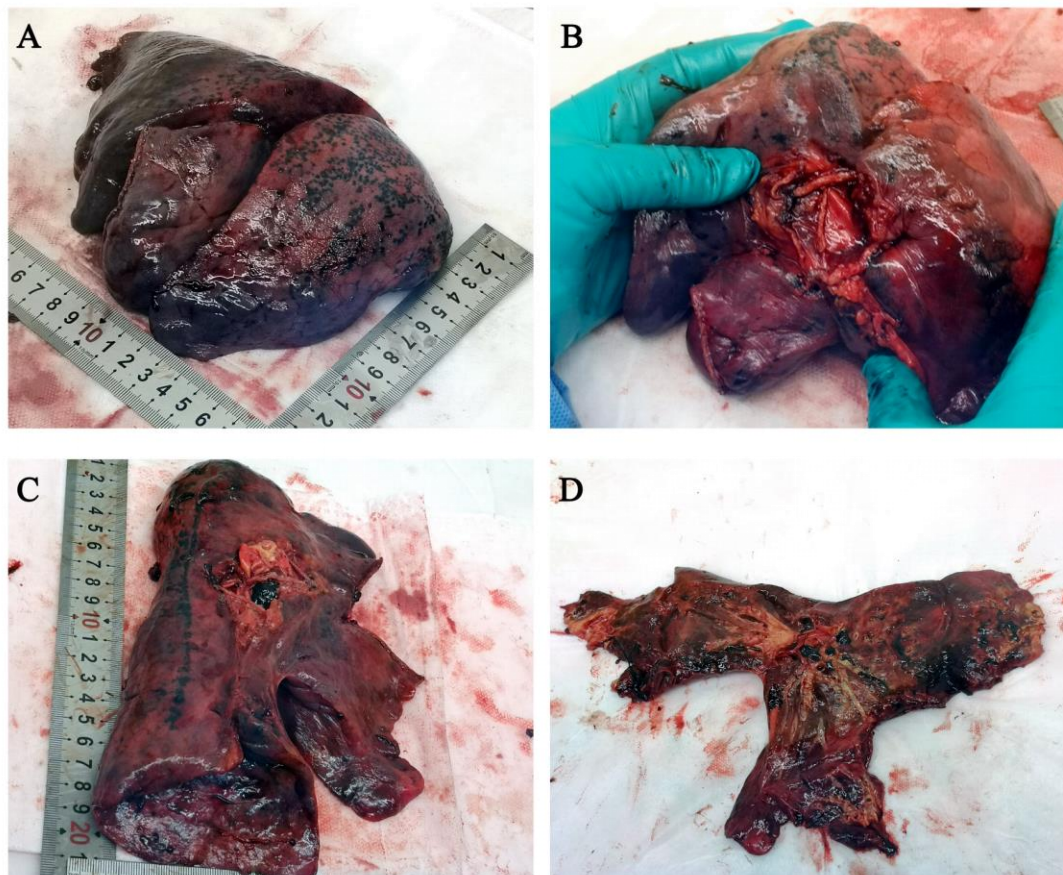
Figure 1. **Lung gross examination**. Gross morphology of the right lung (**A** and **B**) and of the left lung (**C** and **D**). Haemorrhagic necrosis is obvious in the outer edge of pulmonary right lobe.

As showed in **Figure 2**, histopathological findings showed extensive pulmonary interstitial fibrosis with partly hyaline degeneration, and pulmonary hemorrhagic infarct. Small vessels showed hyperplasia, vessel wall thickening, and lumen stenosis and occlusion. Interstitial infiltration of inflammatory cells including lymphocytes, plasma cells and mononuclear cells. On the other side, pulmonary interstitial fibrosis was confirmed by Masson staining, and no other bacterial and fungal infections were detected by special staining.
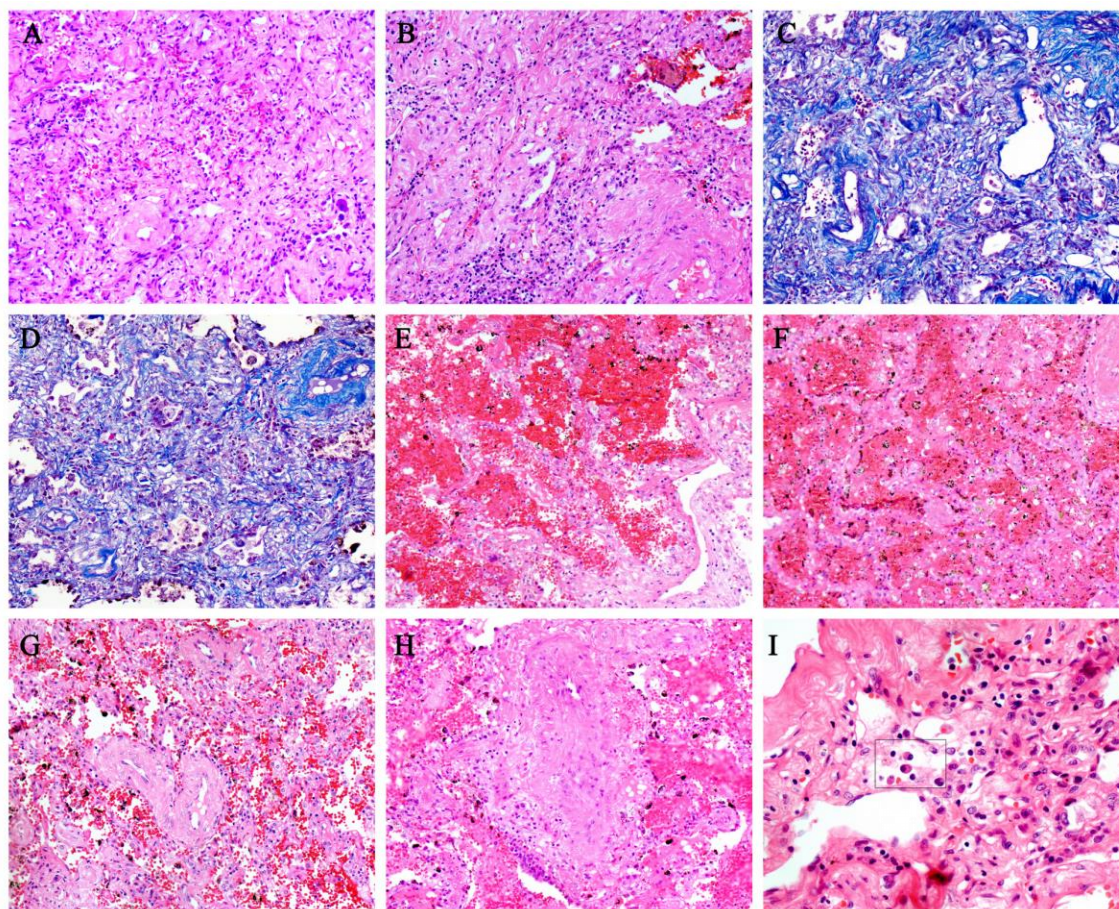
Figure 2. **Pulmonary interstitial histopathological biopsy with critical patient** **A:** Massive pulmonary interstitial fibrosis. **B:** Pulmonary interstitial fibrosis accompanied with partly hyaline degeneration. **C:** Lung interstitial fibrosis by Masson stain. **D:** Interstitial fibrosis by Masson stain. Desquamation of alveolar epithelial cells. **E:** Pulmonary hemorrhagic changes. **F:** Pulmonary hemorrhagic infarct. **G:** Vascular wall thickening and lumen stenosis. **H:** Boangiitis obliterans are surround by inflammatory cells. **I:** Interstitial plasma cells infiltrating(square frame indicates).

There was alveolitis with atrophy, proliferation, desquamation and various changes of squamous metaplasia of alveolar epithelial cells (mainly typeⅡ), as listed in **Figure 3**. The remaining pulmonary alveoli showed thickened septum, necrosis and desquamation of alveolar epithelial cells. In addition, massive fibrinous exudate, multinucleate giant cells and intracytoplasmic viral inclusion bodies were observed. Necrotizing bronchiolitis manifested necrosis of bronchiolar wall and epithelial cells were present in the lumen.
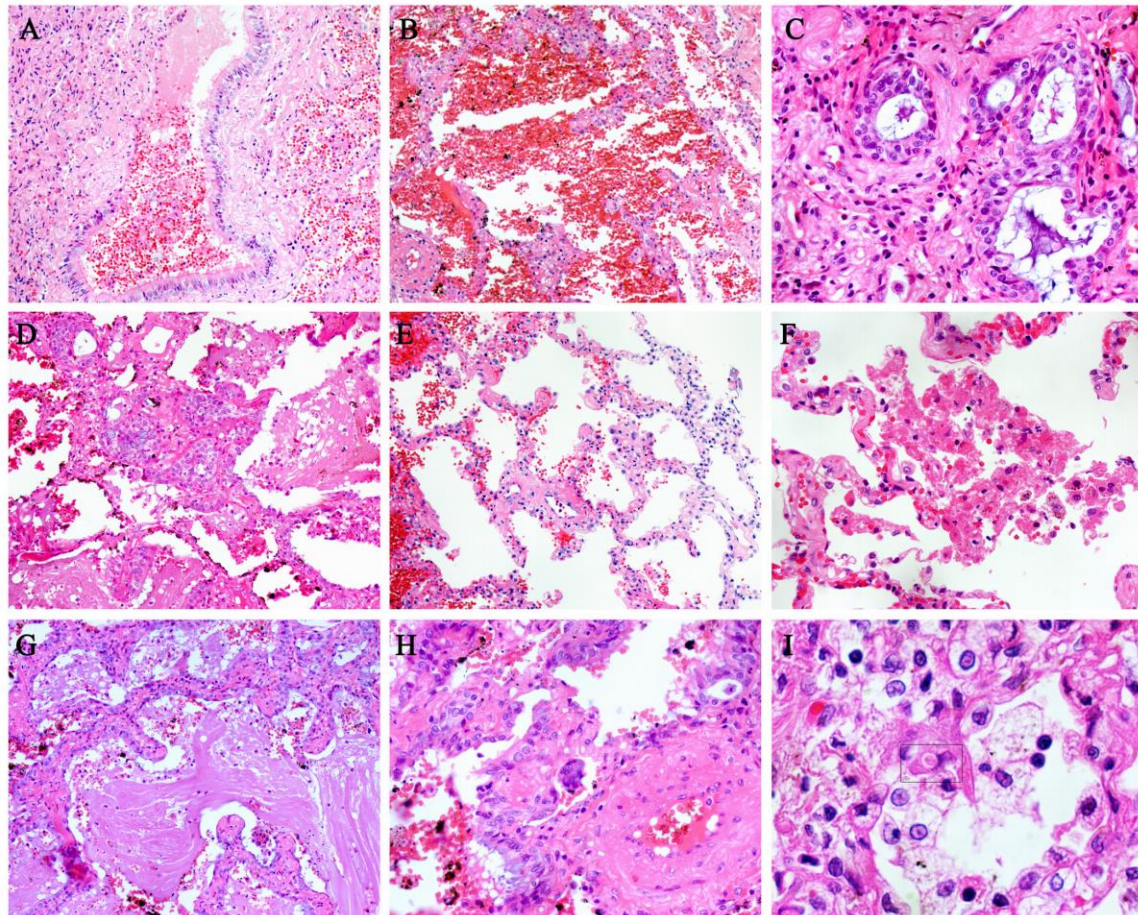
Figure 3. **Pulmonary alveoli changes of COVID-19 biopsy.**   **A:** Necrotizing bronchiolitis, necrotic bronchial epithelial cells are present in the lumen.   **B:** Atrophy of alveolar epithelial cells. **C:** Squamous metaplasia of bronchiole epithelial cells   **D:** Squamous metaplasia of alveolar cells. **E:** Thickened alveolar septum.   **F:** Necrosis and desquamation of alveolar epithelial cells. **G:** Inflammatory cells and massive fibrinous exudate in the lumen.   **H:** Multinucleate giant cell. **I:** Intracytoplasmic viral inclusion body in alveolar epithelial cell (square frame indicates).

Immunohistological findings showed positive for immunologic cells including CD3, CD4, CD8, CD20, CD79a, CD5 and CD38. (**Figure 4**). We found that the positive expressions of immunologic cells were present focally in lung interstitium and near blood vessels. In addition, CD31, TTF1, CK5/6, CK7, CK19, SMA, F VIII and Collagen IV also exhibited positive (some data not shown).
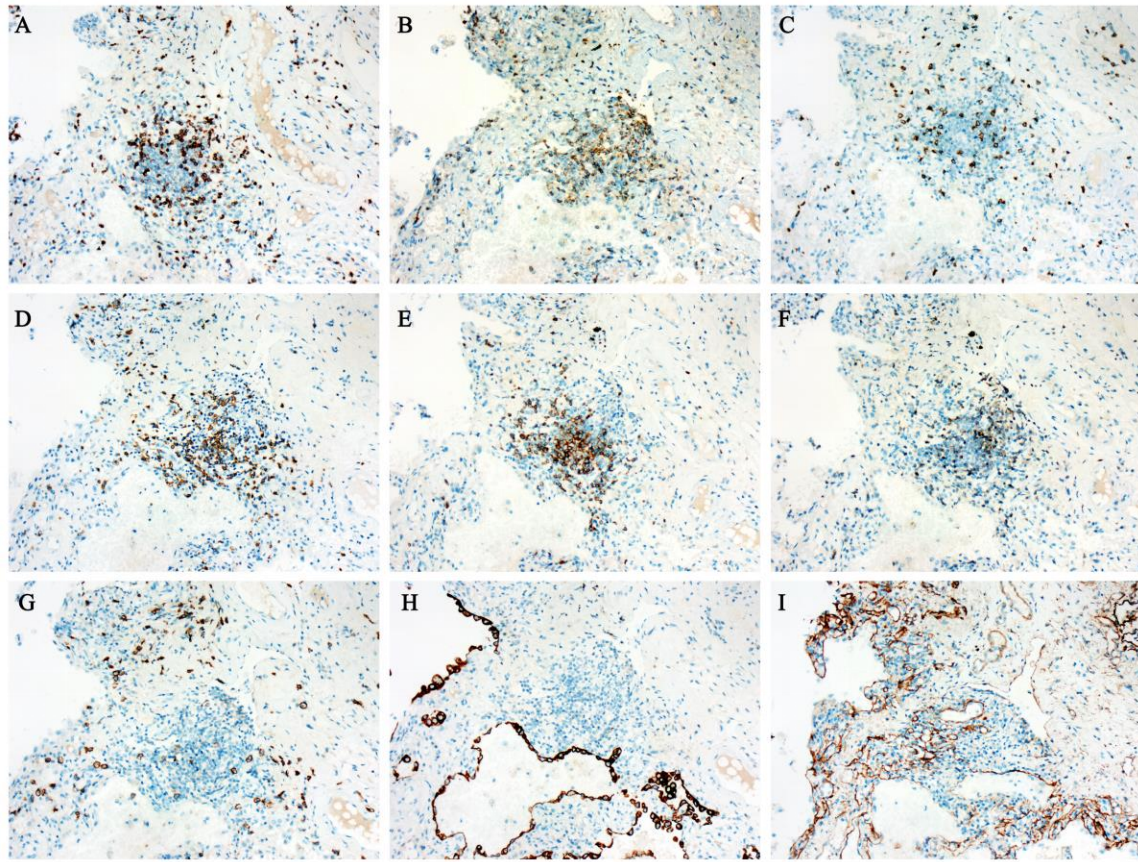
Figure 4. **Immunohistological results in severe COVID-19.** Serial sections showed the positive expressions of CD3 (**A**), CD4 (**B**), CD8 (**C**), CD20 (**D**), CD79a (**E**), CD5 (**F**), CD38 (**G**), CK7 (**H**) and collagen IV (**I**).

Discussion

Novel coronavirus pneumonia caused by SARS-CoV-2 has an worldwide outbreak since it firstly emerged in December 2019, Wuhan city, China.[3,8] As far as we know, no pathological findings of critical patient with COVID-19 have been described. It was reported that the virus homology was over 85% between novel coronavirus pneumonia and severe acute respiratory syndrome (SARS). It means that the pathological changes of COVID-19 might be similar to SARS patient. With regard to the pulmonary pathology of

SARS, Ding and other research groups had found the pulmonary changes including localized haemorrhage and necrosis, pulmonary alveolitis and bronchitis, desquamation of alveolar epithelial cells.[9-11] Actually, in this study, our results also showed the general pulmonary damages including alveolar edema with hemorrhage and bronchiolitis and alveolitis accompanied with inflammatory injury of epithelial cells. Of note, we observed that extensive pulmonary interstitial fibrosis, vascular wall thickening, lumen stenosis and occlusion occurred frequently under the microscopy. These major changes might contribute to critical patients developing severe respiratory failure. On the other side, gross detection found that haemorrhagic necrosis existed predominantly in outer edge of the right lung lobe. This observation brings us two hints as below: 1) It could be one of the main causes of severe patient death. 2) The main lesions of COVID-19 might firstly originate from here.

Recent study indicates that SARS-CoV-2 has the same cell entry receptor ACE2 as SARS-CoV.[12,13] Generally, ACE2 protein is expressed in alveolar cells, bronchial epithelium and vascular endothelium, therefore SARS-CoV-2 protein binds to ACE2 would result in acute lung injury and pulmonary edema. We observed abundant pulmonary edema and hemorrhage, desquamated bronchial and alveolar epithelial cells.
On the other side, cytokine storm links to an excessively exaggerated immune response, and uncontrolled proinflammatory responses, which causes severe organ diseases including lung damages.[14-16] Several representative cytokines have been identified including IL-1β, IL-18, TNF-α, IL-6, IL-8 and IL-10, which are produced and regulated by various immunological cells including CD8 and CD4 T cells.[17] Interestingly, we observed that lymphocytes, monocytes and plasma cells infiltrating into pulmonary interstitium, and these types of inflammatory cells were confirmed by immunohistological

method. As we demonstrate above, many pathological changes occurred in pulmonary interstitium including extensive interstitial fibrosis and vessels lumen stenosis. Therefore, these results might explain why critical patient had acute lung dysfunction.

In summary, we demonstrate the whole pulmonary biopsy histopathology of COVID-19 critical patient, which might provide a better knowledge of the pathogenesis of this disease.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed

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