The web link of this document as follows:

https://nam01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fmp.weixin.qq.com%2Fs%2FUrQmykElMuk68WkvArBTSg&data=02%7C01%7CJi-Bin.Liu%40jefferson.edu%7C66e3a621cfd4438e6b6708d7c0788859%7C55a89906c710436bbc444c590cb67c4a%7C0%7C0%7C637189496238746109&sdata=dvDLLwGyOwl3TZUIy%2ByF6pDGjT6GI82a%2BU%2Bqi6lFI1s%3D&reserved=0

CCUSG-Recommended treatment of severe new coronary virus pneumonia based on critical ultrasound (first edition)

China Critical Ultrasound Research Group (CCUSG), Critical Hemodynamic Treatment Collaborative Group of Chinese Medical Association (CHTCGroup)

Table of Contents

1 Ultrasonographic manifestations of patients with new type of coronavirus pneumonia (NCP)

(A) characteristics of lung ultrasound images in patients with NCP

(B) echocardiographic images of patients with NCP

2 critically ill patients with ultrasound helps to start early treatment of suspected NCP

3 Critical ultrasound helps NCP burst early evaluation of severe events

4 Screening and Severe Grading Assessment of NCP Patients after ICU

1 Screening after entering the ICU

2 Fast and precise severe classification based on critical ultrasound assessment

5 Critical ultrasound guided treatment system in patients with severe NCP

(A) Respiratory therapy for NCP patients under critical ultrasound guidance

(B) The application of critical ultrasound in the circulation management of NCP patients

(3) Critical ultrasound helps to find out the chronic cardiopulmonary disorders of NCP patients in time

(4) Critical ultrasound plays an important role in ECMO management in patients with severe NCP
(5) Critical ultrasound helps to achieve management of organs other than the heart and lungs based on cardiopulmonary oxygen transport organs
(6) Critical ultrasound helps establish a treatment system for severe NCP patients based on severe fine classification
(7) Value of critical ultrasound in the treatment of abnormal reactions in patients with severe NCP
(8) Critical ultrasound helps to define the treatment goals of patients with severe NCP
(9) Critical ultrasound implementation process based on the NCP patient treatment system

6 intensive ultrasound help to improve technical success rate in the patient with severe NCP-related operations

7 intensive ultrasound help to improve the safety and quality of care in patients with severe NCP

8 Infection prevention and control of ultrasound in NCP patients

9 Value of telemedicine and artificial intelligence in the treatment of patients with severe NCP

10 Limitations of treatment and recommendations

In December 2019, unexplained viral pneumonia in Wuhan, China was gradually determined to be caused by a new coronavirus. On January 12, 2020, the World Health Organization (WHO) named the virus 2019-novel coronavirus (2019-novel coronavirus, 2019- nCoV). On February 7, 2020, the National Health Commission of China referred to pneumonia caused by 2019-nCoV as a novel coronavirus pneumonia (NCP). On February 11, 2020, the International Committee on Taxonomy of Viruses (ICTV) announced that the new coronavirus (2019-nCoV) was officially classified as severe acute respiratory syndrome coronavirus 2, SARS-CoV-2). On the same day, the WHO announced that the disease caused by the virus was officially named COVID-19.

So far, tens of thousands of cases have been confirmed. The rate of severe illness is above 10% or higher. The characteristics are often: after the virus invasion, the lung damage continues to increase, causing respiratory failure as the basis, secondary clinical cycle changes and multiple organ function damage. Intensive care has become a major problem urgent and urgently needs to be solved. In recent years, critical

medicine has developed rapidly, and critical ultrasound is one of the most representative advancements in the field of critical medicine. Severe patients are often affected by multiple organ function based on cardiopulmonary oxygen transport organ damage. In line with this, the characteristics of intensive ultrasound monitoring and evaluation are whole-body multi-organ assessment based on cardiopulmonary assessment. At the same time, intensive ultrasound has dynamic, real-time, non-invasive, and repeatable characteristics. It can be used not only for disease assessment, timely detection of problems, but also for Carry out multi-objective integrated dynamic assessment and obtain important data together with other monitoring methods to provide timely and accurate guidance for the adjustment of diagnosis and treatment.

The epidemic was an order, and the intensive doctors went back to war and went into battle. Based on the recommendations of critical experts from all over the country who are involved in the fight against the epidemic in Wuhan, Hubei, this article summarizes the recommendations for the treatment of severe NCP patients based on critical ultrasound, hoping to provide help for the treatment of severe NCP patients.

1 Ultrasound findings of patients with new coronavirus pneumonia

(1) Ultrasound images of lungs in patients with new coronavirus pneumonia

The pulmonary ultrasound characteristics of new coronavirus pneumonia are related to various stages of the patient's examination, the severity of lung involvement, and underlying diseases. Due to its imaging manifestations, the lesions are mainly distributed under the pleura. Easy to find anomalies. It should be emphasized that the lesions are deep and/or pleural is not accumulated, and there are limitations in pulmonary ultrasound, especially early or mild.

From the characteristics of current CT images of the lungs, the natural course of the general patient: the early CT of the fever patients may be negative or atypical, such as only diffuse vascular shadow enhancement, with scattered or large ground glass shadows as the disease progresses, some Patients can exacerbate during exacerbation, showing exudation or

even consolidation. It may be accompanied by bronchial inflation signs, rare pleural effusion, and enter the fiber optic cord imaging performance until absorption. Due to the frequent occurrence of lesions, the range of invasion can be small or large. A thin-layer multidimensional CT examination is required to fully evaluate lung lesions; CT imaging of typical patients with dyspnea or hypoxemia is typical, with multiple lungs scattered or large ground glass shadows. Patients with rapid deterioration can Severe infiltration and even consolidation appear; critically ill patients often include multiple nature lesions, often at different stages, and the lesions change significantly over time.

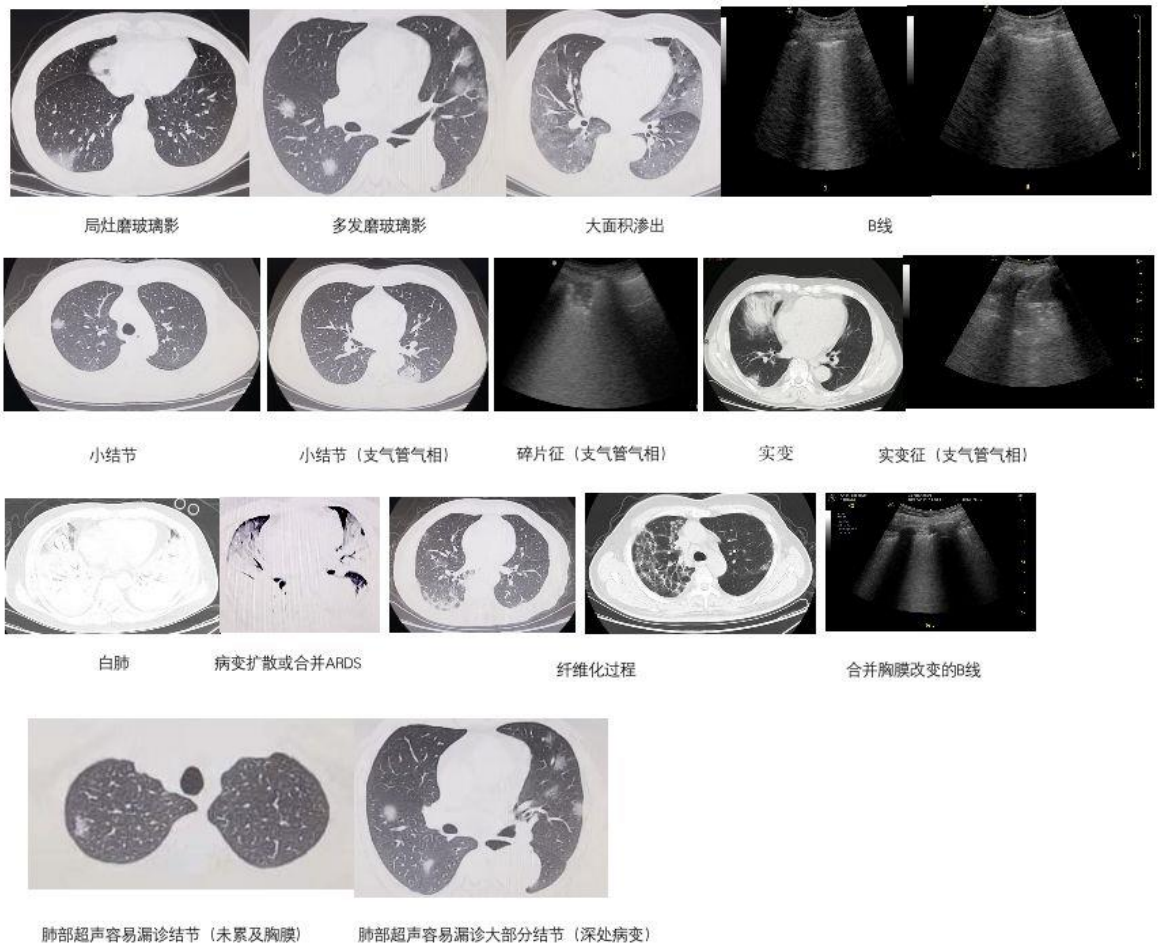


图1 新型冠状病毒肺炎患者的肺部超声影像特点（与肺部CT对应）
武汉大学中南医院供图

Corresponding to the CT imaging features of the lungs (Figure 1), the characteristics of the lung ultrasound images of NCP patients are as follows:

1) The pleural line is thickened to varying degrees;
2) B-lines (B7, B3) and fused B-lines with different degrees can be expressed as focal B-lines and diffuse alveolar interstitial syndrome according to the distribution area;
3) Subpleural consolidation, pulmonary ultrasound manifestations of debris signs;
4) Large-scale consolidation with bronchial inflation signs, pulmonary ultrasound manifestations are tissue-like signs, dynamic bronchial inflation signs;
5) Rare pleural effusions such as jellyfish signs and quadrilateral signs;
6) Multiple abnormalities in the lungs;
7) Focal B-line is the main part in early and mild cases. Alveolar interstitial syndrome and consolidation are the main ones in the advanced stage. Normal A-line of pulmonary ultrasound or pleural line increase with pulmonary fibrosis can be fully recovered during the recovery period. Thickness is accompanied by uneven B-line changes;
8) Special emphasis is given to the fact that if the lesion is deep and/or does not involve the pleura, there is a clear limitation of the lung hyperplasia, especially early or mild;

Pulmonary ultrasound, as part of critical ultrasound, can help evaluate the occurrence and development of NCP lung lesions in critically ill patients, but it is important to remember not to use lung ultrasound alone for early diagnosis and comprehensive deep lung disease assessment. Pulmonary ultrasound does not agree with clinical symptoms, suggesting that the lung CT imaging examination needs to be improved.

(2) Ultrasound images of the heart in patients with new coronavirus pneumonia

In patients with severe NCP, echocardiography can often detect right heart function involvement, and there can also be characteristic changes such as diffuse cardiac enhancement, stress cardiomyopathy, and diffuse cardiac depression. Especially in severe patients with ARDS, there may be different changes in the left heart based on acute pulmonary heart disease changes (Figure 2).

Figure 2 Right heart enlargement, heart movement enhanced (courtesy of Wuhan University Zhongnan Hospital)

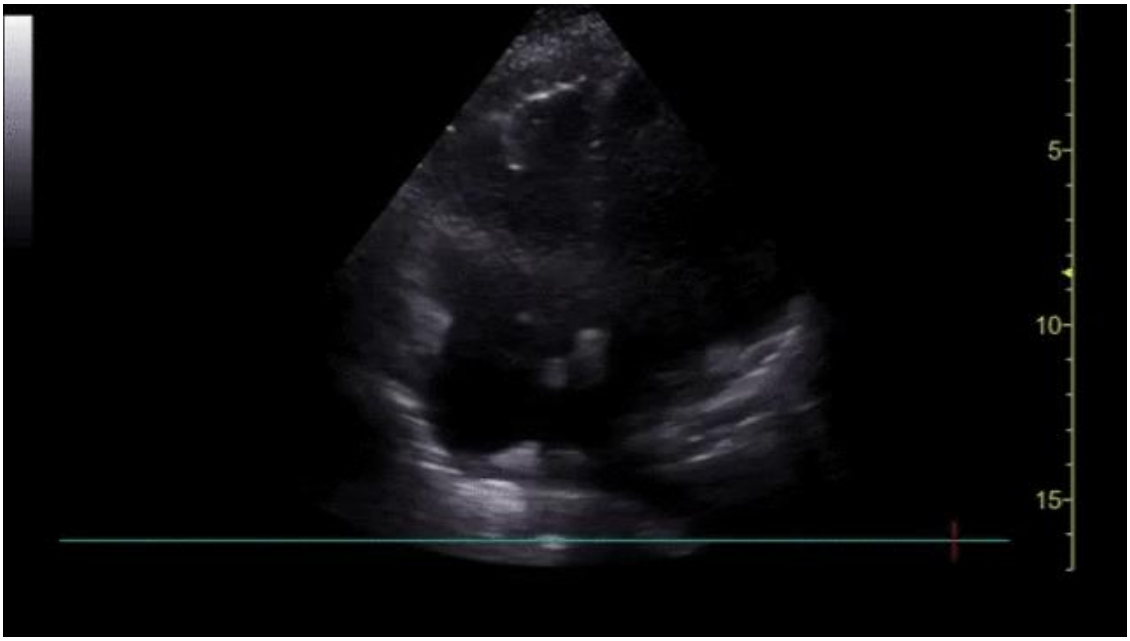


Figure 2 Diffuse heart depression, suspicious left heart stress (Photo courtesy of Zhongnan Hospital, Wuhan University)

2 Critical ultrasound helps patients initiate early treatment during the suspected period of new coronavirus pneumonia

The diagnosis of new coronavirus pneumonia is mainly based on epidemiological history, clinical manifestations, and nucleic acid testing. Due to the technical requirements and timeliness of nucleic acid detection, and patients with new coronavirus pneumonia have characteristics of lung imaging earlier than clinical, experts from various parties actively call for lung CT advancement as a necessary item for preclinical screening of suspected patients. Positive patients immediately start treatment to achieve the goal of early isolation and early treatment. When faced with CT scans in many epidemic areas or patients are critically ill and cannot ensure the safety of the examination, lung ultrasound can also be used as a powerful supplementary means for initial screening, so as to screen out suspected patients as soon as possible and initiate isolation and early treatment (Figure 3) .

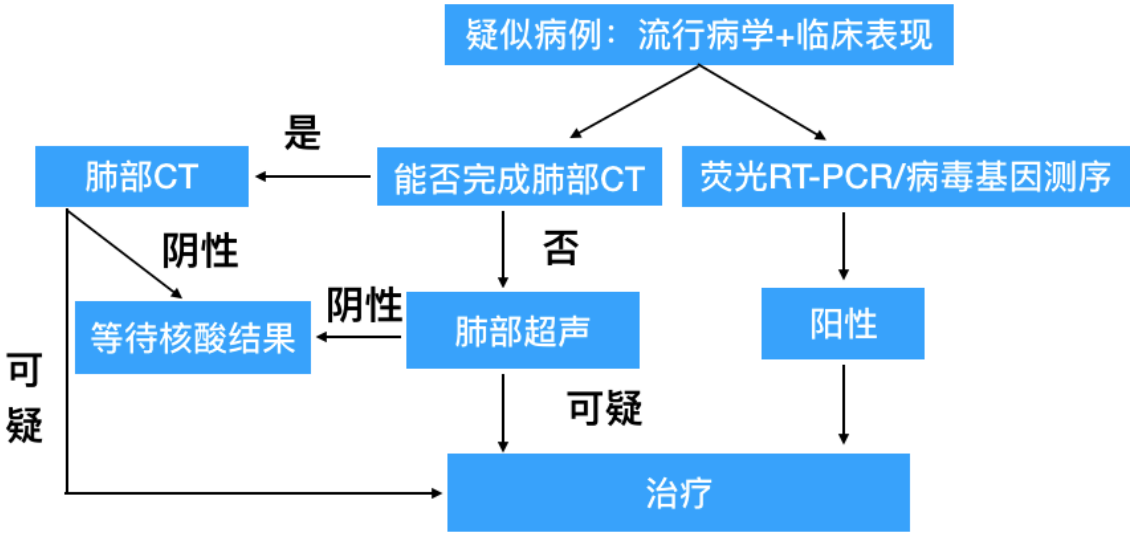


图3 重症超声指导新型冠状病毒肺炎疑似期启动早期治疗中的流程图 中国重症超声

3 Critical ultrasound helps early assessment of severe outbreaks of new coronavirus pneumonia

New coronavirus pneumonia can be divided into mild, clinical common, severe and critically ill according to the severity. The disease can gradually develop, or it can suddenly deteriorate into severe and critically ill in different processes. Prompt clinical identification, early assessment, and rapid severe grading are the basis of treatment and important links to improve prognosis. Severe events include respiratory cycle involvement represented by respiratory failure and shock, and damage to other organs other than the heart and lungs, and they need to be immediately transferred to the ICU or the ICU for intensive treatment (Figure 4).

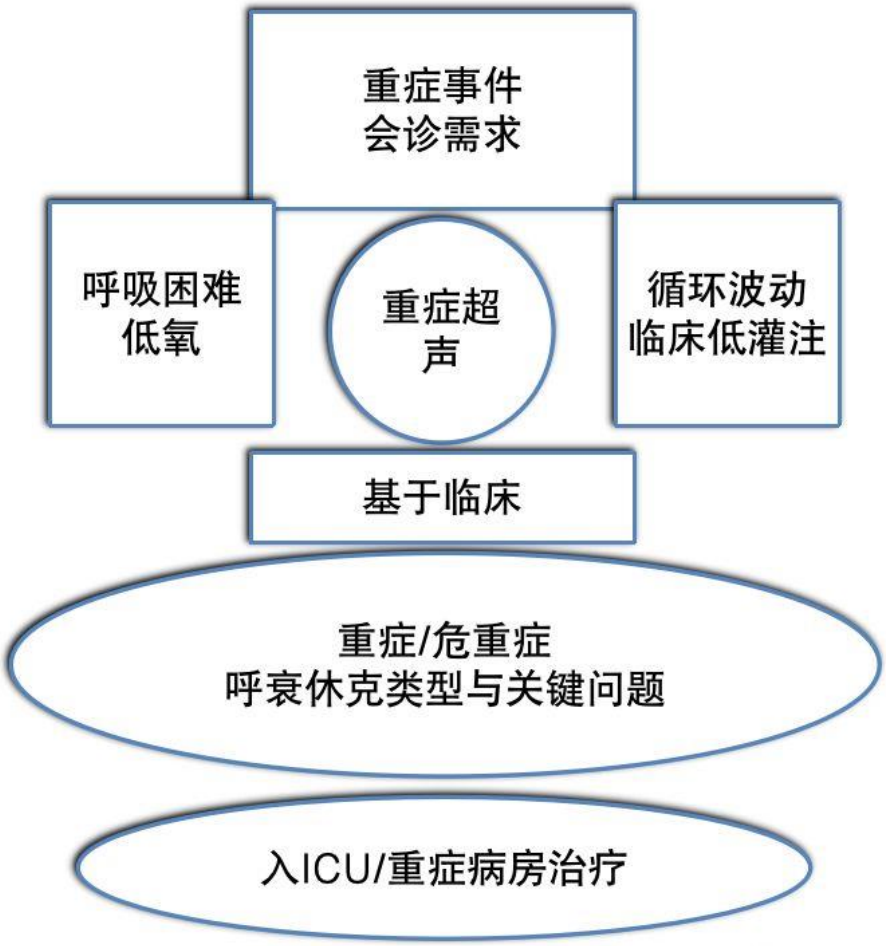


图4 新型冠状病毒肺炎患者突发重症事件的早期评估流程图

Critical ultrasound helps to accurately assess the occurrence of severe events in the NCP at an early stage. Cardiopulmonary ultrasound screening

programs can be preferentially selected, which can be implemented in time for the classic critical emergency consultation program (Critical consultation ultrasound examination / Critical care ultrasound examination, CCUE, Figure 5).

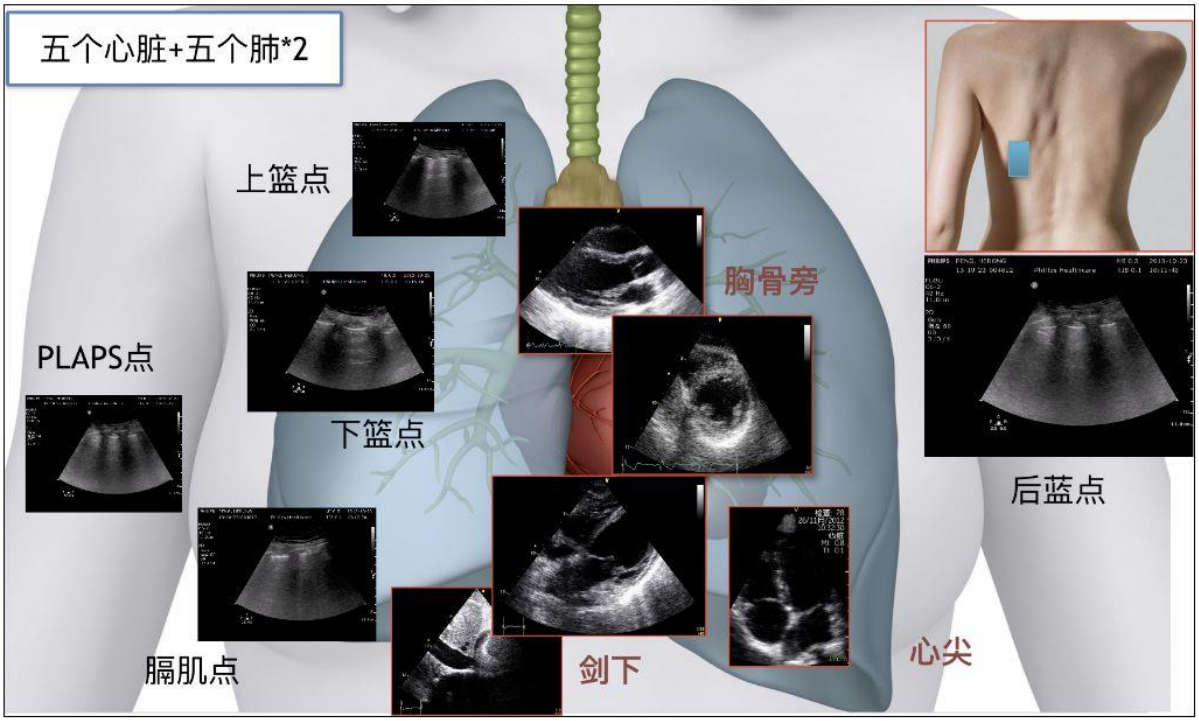


图5 经典重症急会诊方案(CCUE)

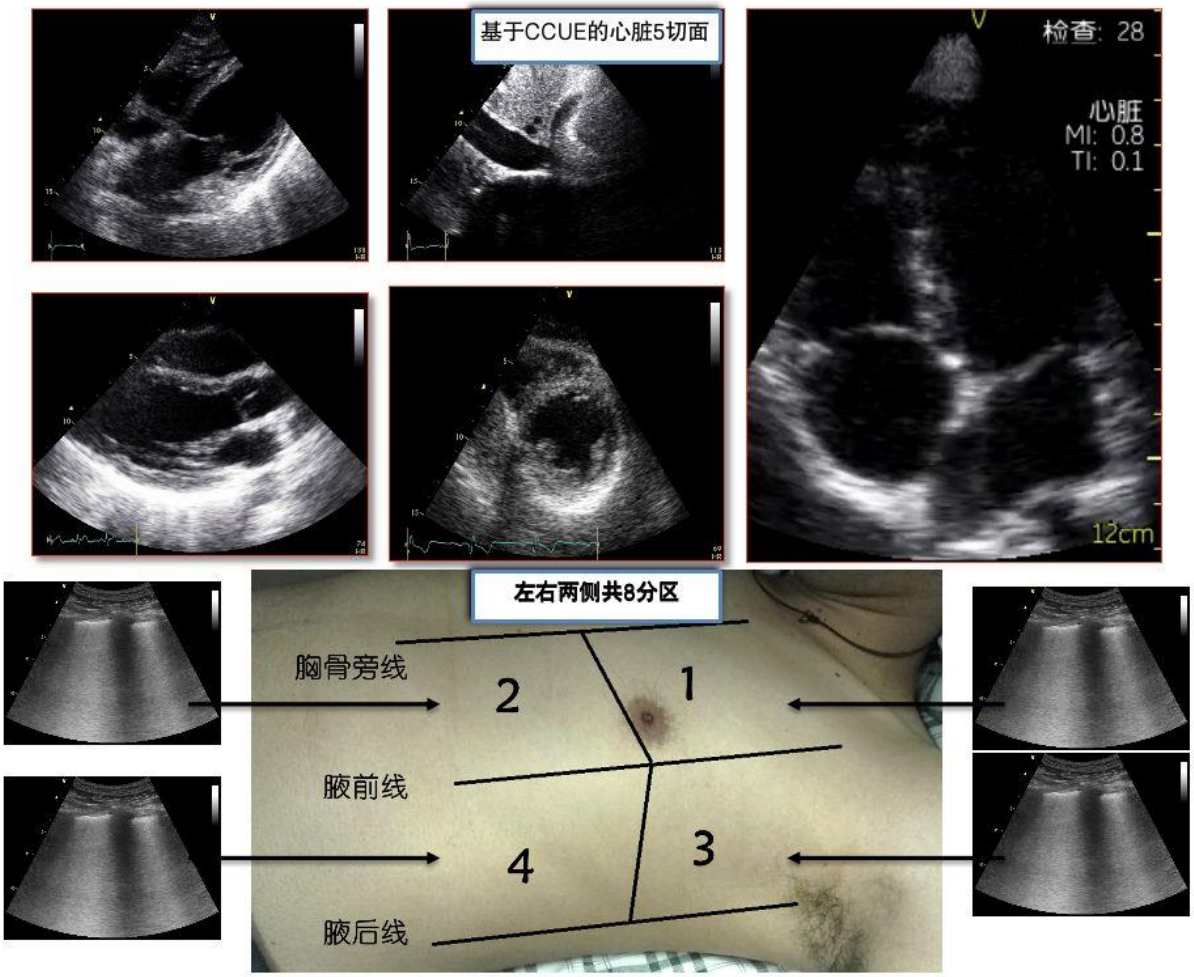


图6 修改版M-CCUE(Modified-CCUE) 流程

If necessary, a modified version of the M-CCUE (Modified-CCUE, Figure 6) scheme is used, in which the echocardiography still selects the four-cavity under the sword, the inferior vena cava, the parasternal long axis, the parasternal series short axis, and the apical four-cavity plane. For lung ultrasound, choose 8- or 12-segment method to avoid or reduce the missed evaluation of lesions. The eighth subarea focuses on the assessment of pulmonary interstitial syndrome, and the twelfth subarea mainly evaluates different parts of the lung and different lesions.

In view of the fact that the lung damage of the new type of coronavirus pneumonia is multifocal, and has the characteristics of bottom-up and

outside-in, it is recommended to use the lung 12-division method for screening under conditions, which will help improve the detection of positive lesions. rate. The specific zoning method uses the patient's parasternal line, anterior axillary line, posterior axillary line, and paraspinal line to divide the thorax into anterior, lateral, and posterior chest wall. There are 6 areas in each area, and each area is further divided into 2 areas, up to 12 areas. .

Lung ultrasound can also be performed with a semi-quantitative examination method. The scoring criteria are:

N: Normal (A line or 2 or less independent B lines);
B1: Moderate reduction in lung inflation, multiple distinct B lines can be distinguished;
B2: Lung inflation is severely reduced, multiple fused B-lines;
C: consolidation of the lungs, the lungs present a tissue-like structure with dynamic bronchial inflation signs;
AT: Lung atelectasis. The lungs show a tissue-like structure with static bronchial inflation signs, which are the same as the lung consolidation score.

For a given area, take the worst value and score according to N = 0, B1 = 1, B2 = 2, C = 3, and add the scores of each area for a semi-quantitative total score of 0-36 points.

In either case, the following information needs to be obtained within 10 minutes:
1. Is there a characteristic lesion that has invaded the pleura (B-line, consolidation, lung point, quadrilateral sign, etc.), and which area or areas are distributed?

2. Whether cardiac function is involved (inhibition and enhancement), right heart, left heart and full heart function status, capacity status (too much or too little, intermediate status).

4 Screening and Severity Grading Assessment of New Coronavirus Pneumonia in ICU Patients

1 Screening after entering the ICU

After the patient is transferred to the intensive care unit, the first time application of critical ultrasound to evaluate the cardiopulmonary oxygen transport organs and important oxygen consumption organs can quickly detect the presence of chronic heart disease and lung disease, and early warning of treatment-related risks.

B-line number of lung ultrasound imaging, lesion area, lung ultrasound score, etc. can help judge the severity of lung lesions, assist in the development of oxygen therapy for patients with new type of coronavirus pneumonia, alert the development trend of the disease, and realize continuous dynamic monitoring Assess the evolution of the condition and the effect of treatment. Combining the results of rapid cardiopulmonary ultrasound screening with clinical evaluation of patients and assessment of multifocal multilobed lesions of lung CT images can quickly determine the etiology and status of severe illness and make treatment decisions.

It is recommended to use the revised version of the A-CCUE rapid procedure for the intensive ultrasound screening process, which is based on the M-CCUE procedure of the 12-segment lung method, which is added to the evaluation of the inferior vena cava and the key hemodynamic parameters: Quantitative measurements of diameter, left ventricular ejection fraction, and left ventricular outflow tract velocity time integral (VTI) (Figure 7).

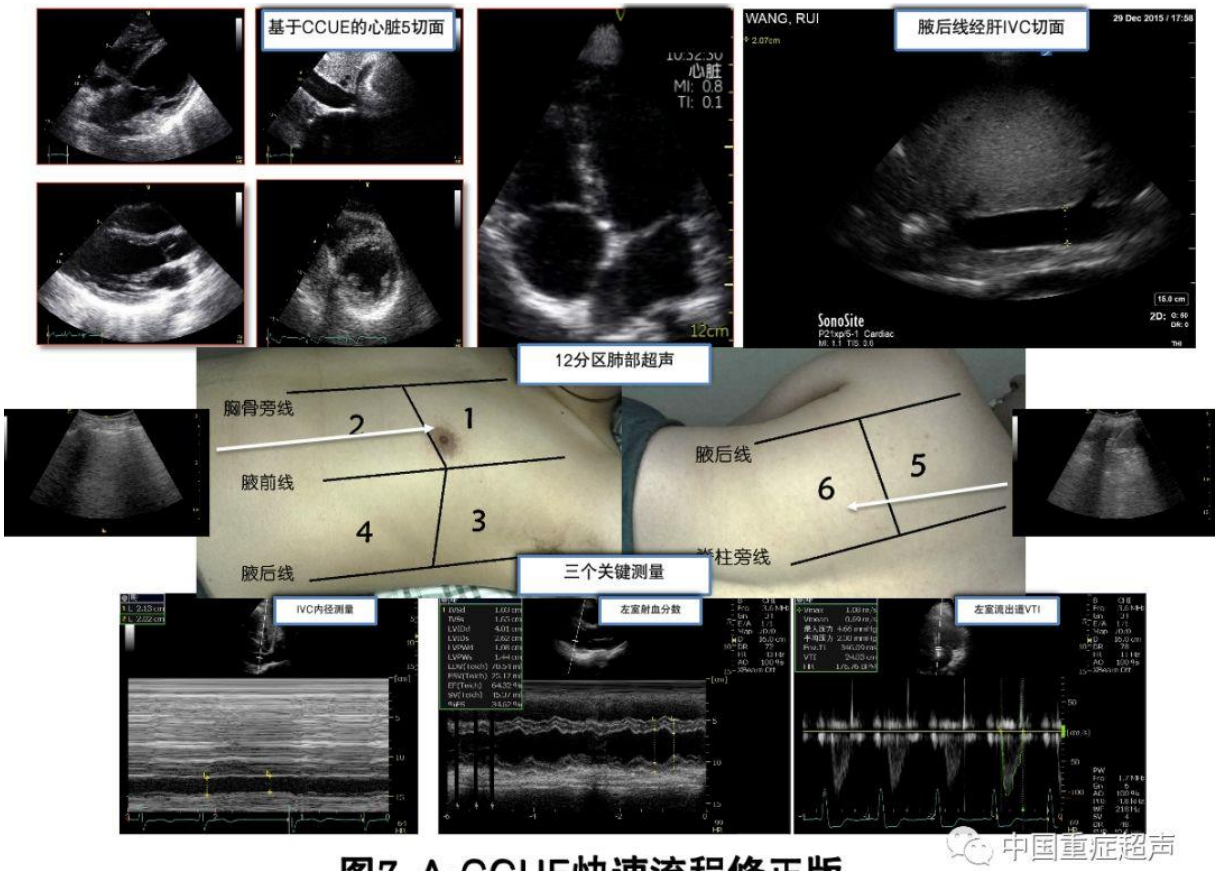


图7 A-CCUE快速流程修正版

2 Fast and precise severe classification based on critical ultrasound assessment

By rapid cardiopulmonary ultrasound assessment, combined with clinical manifestations and CT images of the lungs, patients can be quickly divided into simple respiratory failure, respiratory failure combined with cyclic fluctuations, respiratory failure combined with shock / cardiovascular failure, and respiratory failure combined with shock / cardiovascular Failure is accompanied by damage to organs other than the heart and lungs, respiratory failure with cardiac arrest / cardiopulmonary resuscitation grade 5 and simple pneumonia accompanied by special grades of non-cardiopulmonary organ insufficiency (Figure 8). Fine-grained severity can help make decisions about monitoring intensity, treatment options, and assessment of prognosis.

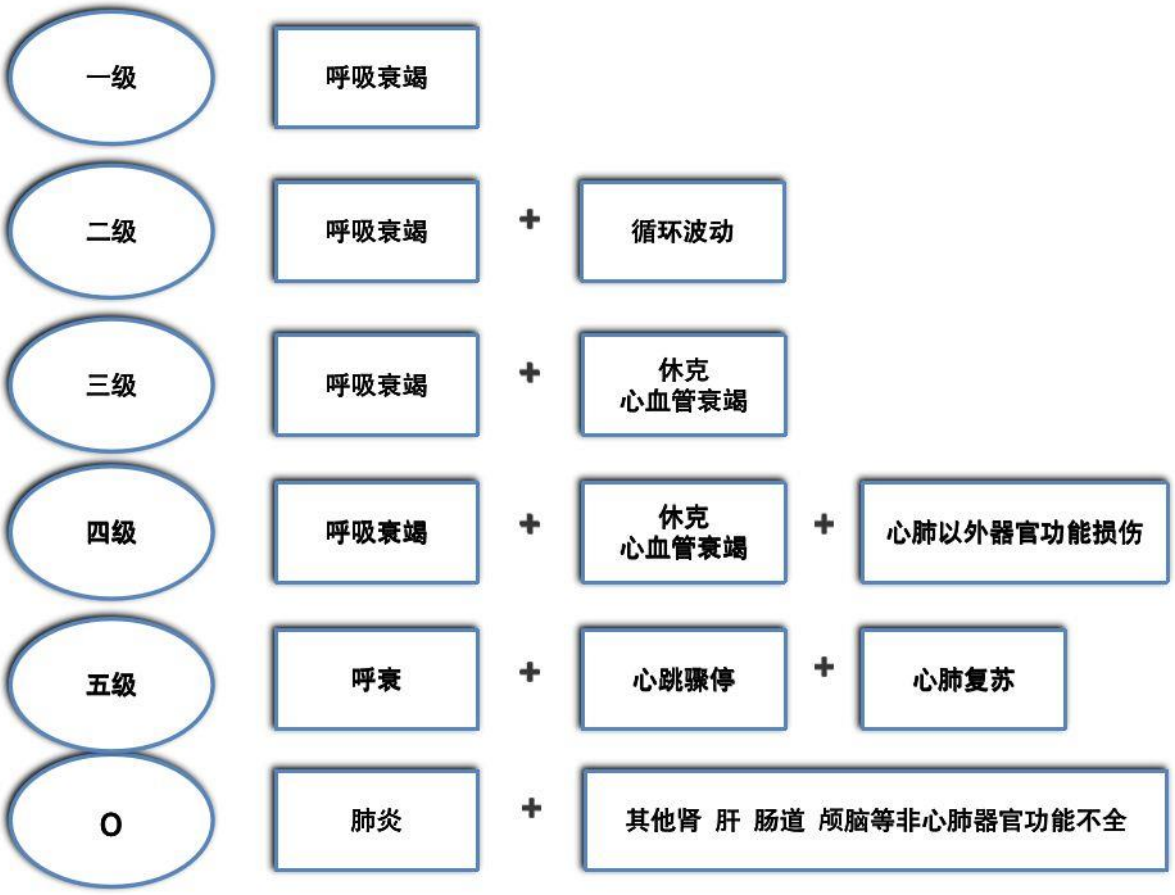


图8 新型冠状病毒肺炎患者的精细重症分级

5 Treatment system for patients with severe new coronavirus pneumonia guided by critical ultrasound

(A) Critical ultrasound-guided breathing therapy for patients with new coronavirus pneumonia

The lung injury of new coronavirus pneumonia originates from two parts: primary injury and secondary injury.

The exact mechanism of the primary injury is currently unknown. Existing studies suggest that angiotensin-converting enzyme 2 (ACE2) is used to

infect cells and promote the production of AngⅡ, which activates AT1a receptors in the lung tissue, induces bronchial smooth muscle contraction, and increases pulmonary vascular permeability. Promote lung fibroblast proliferation, induce alveolar epithelial cell apoptosis, and play an important role in inducing acute lung injury.

Secondary injuries are mainly related to the body's inappropriate stress response, abnormally-driven spontaneous breathing and high circulation dynamics, the distribution of gravity-dependent lesions, and the intervention-related injuries of mechanical ventilation.

The key to the treatment of primary injury lies in early diagnosis and early antiviral treatment. The secondary injury lies in prevention and avoidance under active protection. The possible mechanisms and key treatment measures for primary and secondary lung injury in NCP patients are shown in Figure 9.

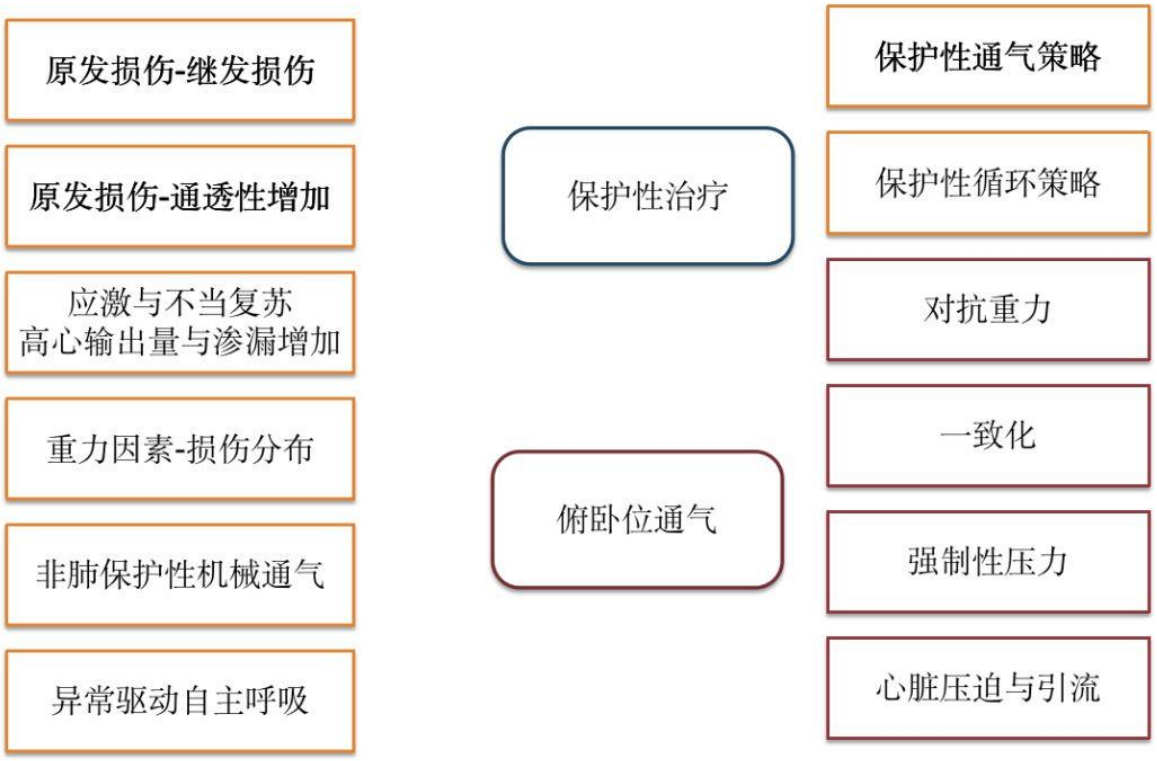


图9 新型冠状病毒肺炎患者原发与继发肺损伤的可能机制与关键治疗措施

The specific details are as follows:

1. Critical ultrasound helps to quickly screen for the cause of respiratory failure in patients with new coronavirus pneumonia

The cause of respiratory failure in patients with new coronavirus pneumonia is mainly related to lung injury, but other causes of respiratory failure cannot be ignored, such as airway, chest cavity, chest wall compliance and pulmonary blood vessels, and cardiogenic factors, etc., screening for respiratory failure The reason is crucial in the treatment process and needs to be consistent throughout, especially when simple lung injury cannot explain the clinical manifestations of respiratory failure. The process uses various schemes based on classic CCUE, such as M-CCUE. The evaluation is based on rapid qualitative analysis, which is necessary. When using a fine evaluation process and evaluation path.

2. Pulmonary ultrasound can assist in the development of oxygen therapy for patients with new type of coronavirus pneumonia, alert the development trend of the disease, dynamically monitor the evolution of the disease, and evaluate the treatment effect

The new coronavirus pneumonia diagnosis and treatment plan (trial version 5) emphasizes that patients with severe illness should receive oxygen therapy in time to avoid persistent hypoxemia. Decide on the type of oxygen therapy (nasal catheter or mask oxygen, high-flow nasal catheter oxygen therapy or non-invasive mechanical ventilation, invasive mechanical ventilation) according to the severity of respiratory distress and / or hypoxemia, and assess whether the remission is timely. Attention should be paid to the different effects of different oxygen concentrations of oxygen therapy to avoid prolonged high concentration oxygen therapy.

In the course of treatment, when to switch from non-invasive to invasive mechanical ventilation and how to dynamically evaluate changes in lung conditions are difficult points in treatment decision-making. Lung ultrasound can achieve dynamic continuous assessment, dynamically monitor the evolution of the condition, and evaluate the treatment effect, such as: B The increase and decrease of the line, the increase and

decrease of the B-line area, and the increase and decrease of the realizing area and volume.

3. Critical ultrasound helps guide and guarantee the implementation of lung protection ventilation in patients with new coronavirus pneumonia

The use of non-invasive mechanical ventilation and / or high-flow oxygen therapy cannot stably maintain SpO2 above 90%, cyclic fluctuations and obvious respiratory distress symptoms (abnormal driving of spontaneous breathing, excessively fast breathing, large assisted respiratory muscle movement, excessive Ventilation, irritability) patients should be intubated as early as possible and implement lung protective ventilation strategies for respiratory support.

It is necessary to avoid as far as possible clinically patients receiving invasive mechanical ventilation who already require high-concentration oxygen breathing support before intubation, leading to severe classification after intubation according to the ARDS Berlin definition. At this time, protection strategies such as low tidal volume, low plateau pressure, high PEEP, muscle relaxants as appropriate, and prone position (more than 12 hours per day) should be routinely implemented after intubation. If refractory hypoxia is an indication for lung expansion, it is recommended to use ultrasound to assess the potential for expansion and the effect of lung expansion. Pulmonary compliance is often poor in patients with pulmonary ultrasound showing multiple sites of large area consolidation or fusion of the B-line. Long-term high-parameter invasive mechanical ventilation may aggravate breathing and related organ damage. Patients who still have hypercapnia or severe acute pulmonary heart disease (ACP) after proper invasive ventilator treatment should consider ECMO early. To better protect the lungs and right heart.

Specific recommendations for the implementation of lung protection in patients with new coronavirus pneumonia are as follows:

3.1 Expanded protective mechanical ventilation strategy based on traditional small tidal volume and low platform pressure

Based on the mechanism of lung injury, NCP patients emphasize following traditional small tidal volume, low plateau pressure, and high PEEP to maintain appropriate oxygen and carbon dioxide targets; at the same time, they need to pay attention to the lung damage caused by abnormally driven spontaneous breathing and respiratory fluctuations, and emphasize clinical practice The importance of maintaining respiratory stability. These include timely application of muscle relaxation, prone position ventilation, etc., which together with traditional protective ventilation strategies form an expanded protective ventilation strategy, namely the PV (Protective ventilation) strategy (Figure 10).

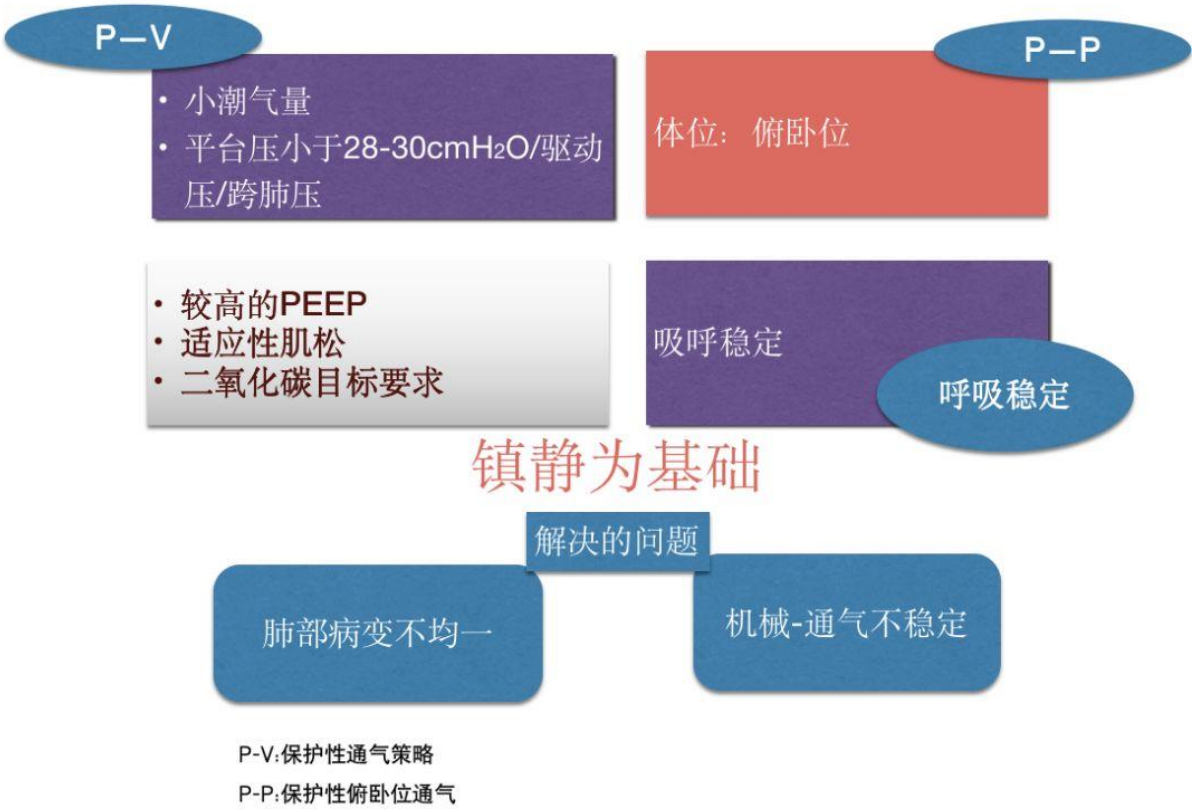


图10 新型冠状病毒肺炎的扩大保护性通气策略

3.2 Dynamic lung ultrasound examination is an important guarantee to achieve the goal of small tidal volume

Pulmonary lesions are exacerbated, often gravity-dependent and heterogeneous, requiring a small tidal volume to achieve lung protection. Pulmonary ultrasonography with 8 and especially 12 subdivision examinations is compatible with the characteristics of gravity dependence and is helpful for clinical small tidal volume management. At the same time, dynamic pulmonary ultrasonography can detect changes in lung lesions in a timely manner under small tidal ventilation (Figure 11).

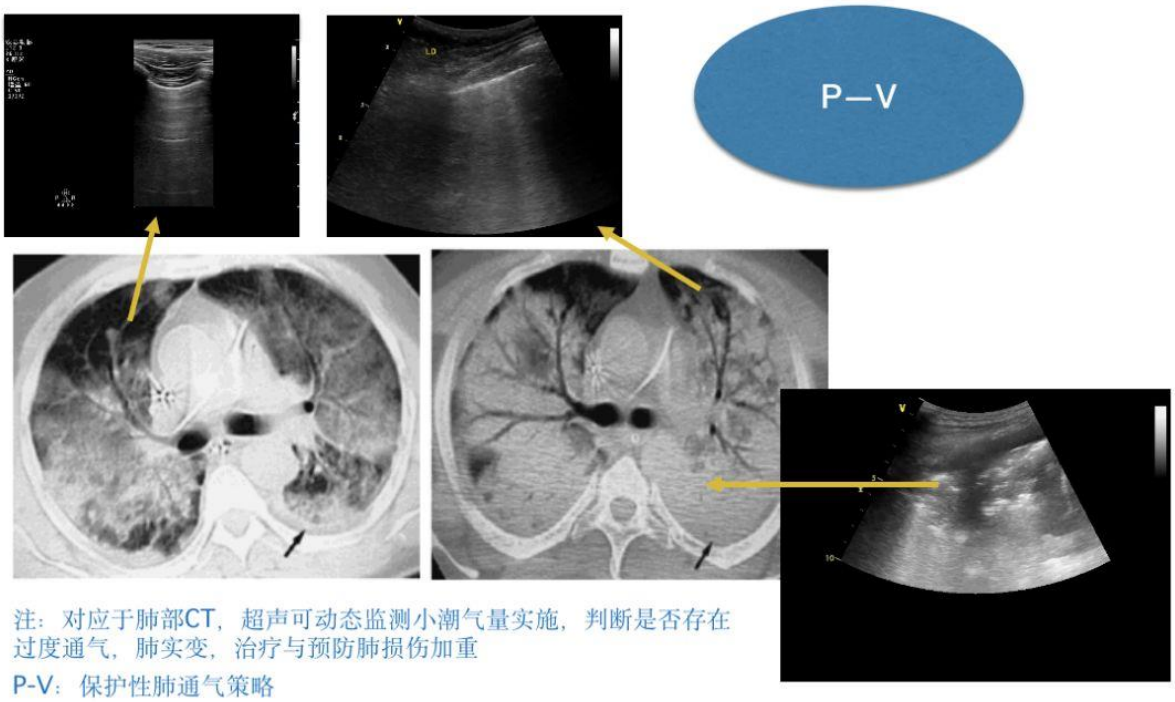


图11 动态肺部超声检查监测小潮气量目标实施

3.3 Diaphragm ultrasound helps assess and select spontaneous breathing intensity

Abnormally enhanced respiratory drive, resulting in significantly increased spontaneous breathing, is an important cause of lung injury in patients with NCP. Unstable breathing conditions and obvious breathing fluctuations also need attention. The evaluation of diaphragm thickness and thickening rate

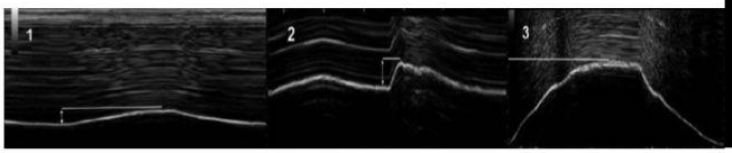
using diaphragm muscle ultrasound is helpful for choosing appropriate spontaneous breathing and stable breathing state. (Figure 12)

膈肌位移正常值（cm）

P—V

膈肌增厚率

正常值	平静呼吸	吸气实验－“嗅”	最大深呼吸
男	1.8±0.3	2.9±0.6	7.0±0.6
女	1.6±0.3	2.6±0.5	5.7±1.0



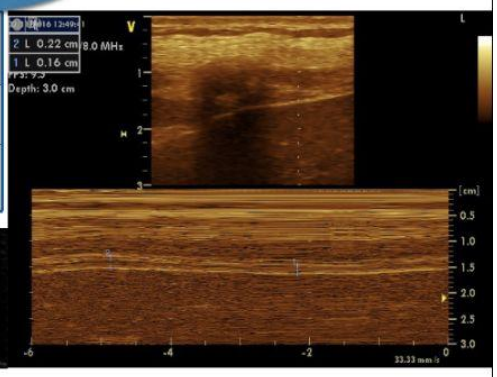


图12 超声膈肌位移与膈肌增厚率选择合适自主呼吸与稳定呼吸状态

3.4 Critical ultrasound helps to evaluate and manage prone ventilation in patients with new coronavirus pneumonia

When patients with severe new type of coronary virus pneumonia undergo mechanical ventilation, the oxygenation index is lower than 150mmHg, the heterogeneity of pulmonary lesions is obvious, or prone position therapy can be initiated when combined with right ventricular dysfunction is protective prone Position ventilation (Protective prone position ventilation, PP).

In the prone position, the severity of lung retension in the gravity-dependent area can be assessed by critical ultrasound, and the effectiveness of prone position treatment can be predicted by the pulmonary ultrasound semi-quantitative scoring method. And guide the time and frequency of prone treatment. Pulmonary ultrasound assessment partitioning method in prone position The back is divided into 3 sections by the spinal line, scapular line and posterior axillary line, each section is equally divided into upper, middle and lower 3 areas, each side is removed by the scapula There are 16 inspection areas in the occluded area, and the inspection method of each area is the same as that of the 12-zone scheme (Figure 13).

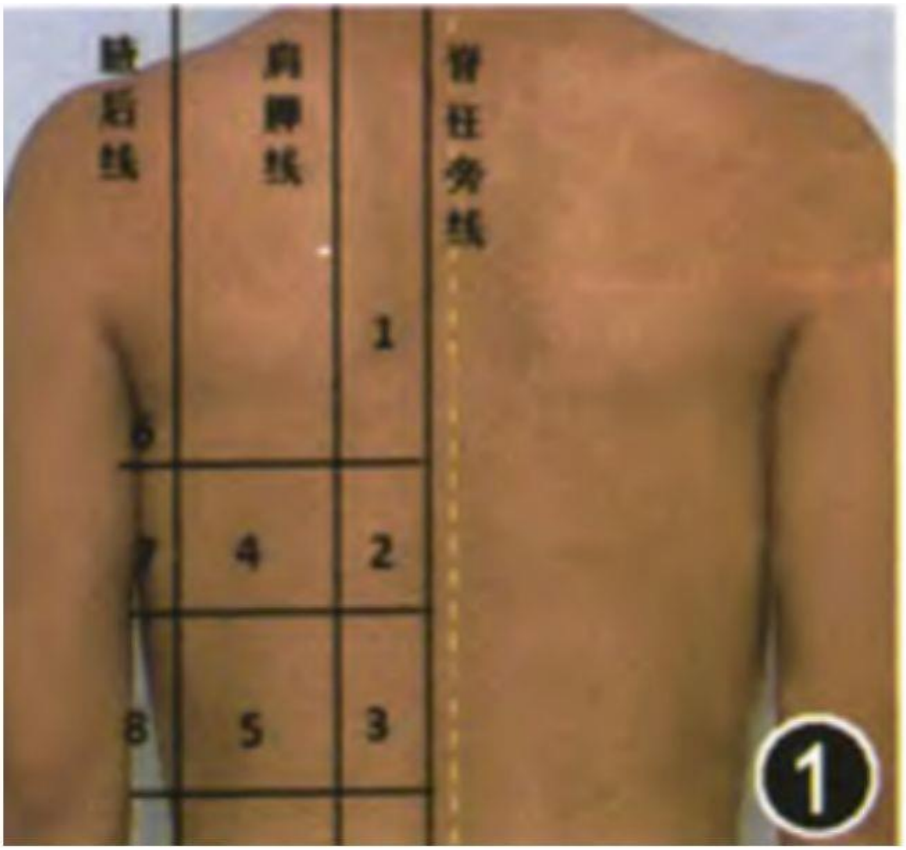


图13 俯卧位通气治疗超声检查区域示意图

During prone position therapy, dynamic semi-quantitative scoring is important and beneficial. At the same time, deep sedation or even muscle relaxation treatment is often required in the prone position, which will affect the circulation. It also needs to be combined with ultrasound hemodynamic monitoring and evaluation to select a more suitable cardiac output to protect the pulmonary circulation.

4 Critical ultrasound helps make decisions on lung recruitment strategies for patients with refractory hypoxia due to new coronavirus pneumonia

When patients with new type of coronavirus pneumonia undergo invasive mechanical ventilation treatment, pulmonary ultrasound can

comprehensively judge the potential of lung expansion based on the uniformity and severity of lung lesions, the presence or absence of dynamic bronchial signs, and tidal lung retension. The operation procedure can be evaluated by qualitative or semi-quantitative ultrasound grading, to understand the conditions, time and effect of re-expansion, and to avoid barotrauma and circulatory disturbance caused by lung re-expansion, helping to choose the appropriate PEEP level.

It needs to be repeatedly emphasized that in patients with severe NCP, lung recruitment should be implemented with caution, including the following:

1) Whether there is clinical refractory hypoxia;
2) Judgment of the safety of lung re-circulation;
3) Assessment of lung recruitment potential;
4) Evaluation of lung recruitment process;
5) Evaluation of effects after lung re-expansion;
6) Evaluation of complications during lung recruitment.

5. Critical ultrasound can help patients with new coronavirus pneumonia achieve a protective lung circulation management strategy

Using critical ultrasound to monitor volume and cardiac function, including VTI close to cardiac output (CO), is conducive to accurate circulation management. The lung is an organ that receives almost 100% CO, and it is also the backward organ of the left ventricle. The precise circulation management can clearly reduce the occurrence and development of pulmonary exudation and edema. At the same time, when choosing liquid and vasoactive drug treatment, observe the microcirculation Five Avoidance Principles: Avoid high perfusion, dilution, leakage, high central venous pressure (CVP), too high single vasoactive drugs, which are good for lung protection, that is, Protective circulatory management PC) Figure 14.

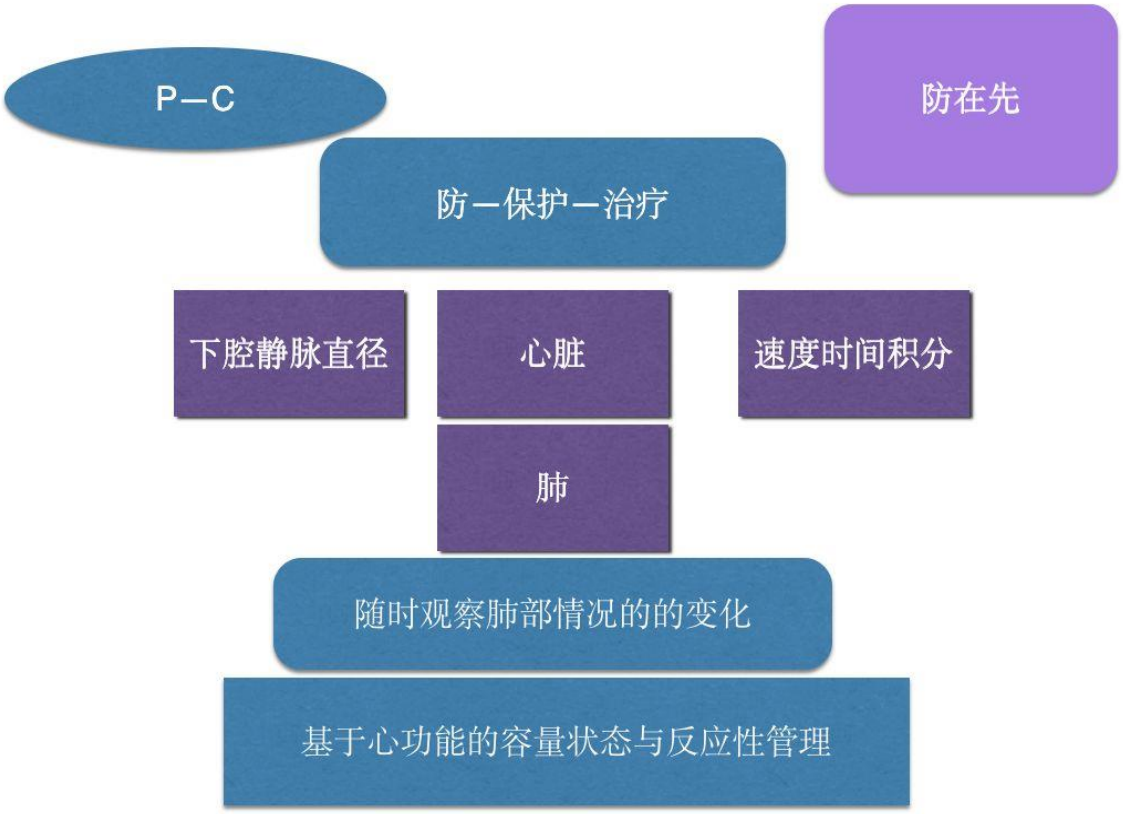


图14　新型冠状病毒肺炎的肺保护性循环支持策略（PC）

6 Critical ultrasound-guided protective treatment strategies and layered management for patients with new coronavirus pneumonia

The key to preventing secondary injury in patients with NCP is to implement protective lung ventilation and circulation management strategies (Figure 15). Under the guidance of critical ultrasound, precise circulation management and protective ventilation strategies are implemented to achieve lung protection and reduce the occurrence and development of ARDS; at the same time, to reduce pulmonary artery pressure, reduce the occurrence of acute pulmonary hypertension and protect the right heart function, and reduce the occurrence and development of ACP the goal of.

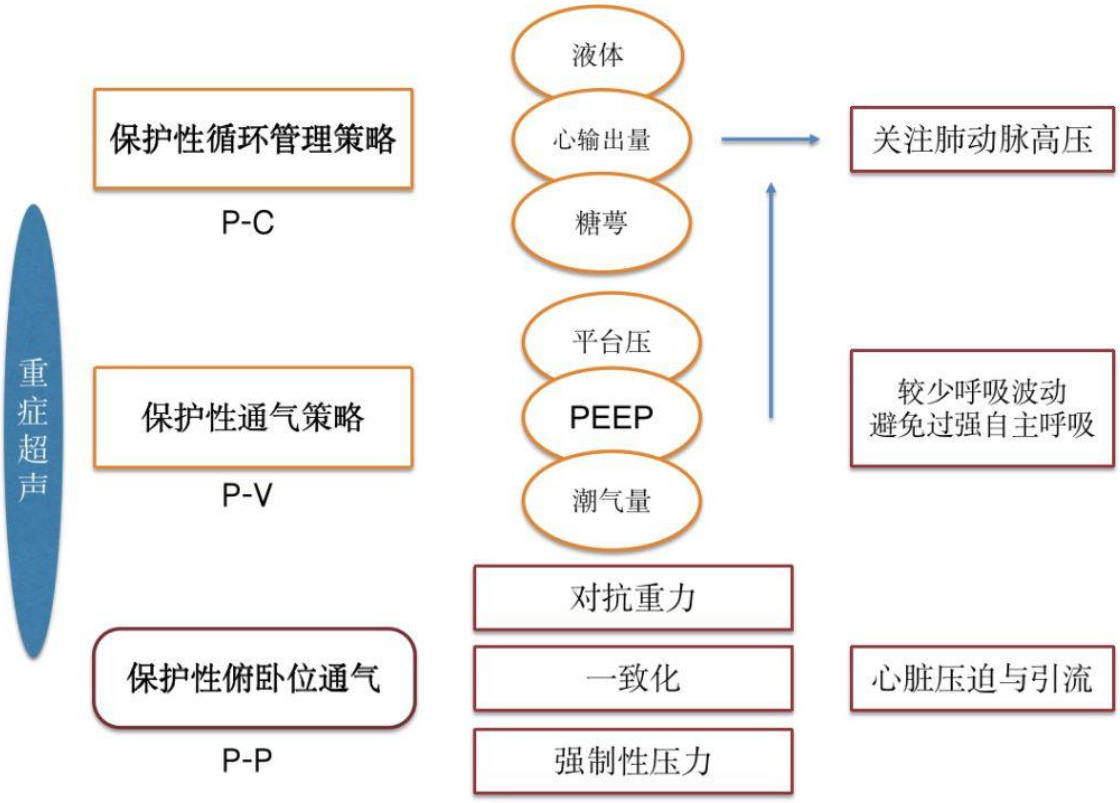


图15 重症超声指导的新型冠状病毒肺炎保护性治疗策略

Similar to ARDS caused by other reasons, layered management is necessary because NCP's lung damage is often from scratch to light and from severe to severe. From the identification of high-risk factors to prevent lung injury, to the implementation of pre-emptive protective strategies to prevent the development of lung injury to mild lung injury, and to the implementation of protective treatment to improve outcome in moderate to severe lung injury, the concept of protective treatment must be continued throughout (Figure 16).

7. Critical ultrasound helps accurate offline implementation of patients with new coronavirus pneumonia

Offline is a very important part of mechanical ventilation in patients with new coronavirus pneumonia. The evaluation of the patient's cardiac function, diaphragm function, and lung semi-quantitative score before and after

offline (Figure 17) can help to grasp the best offline timing, and at the same time evaluate the reasons that may cause offline failure, adjust the treatment plan in time, and maximize The degree of avoidance of patients failing offline or even re-injury caused by failure of extubation may reduce patient mortality and infection rates of medical staff.

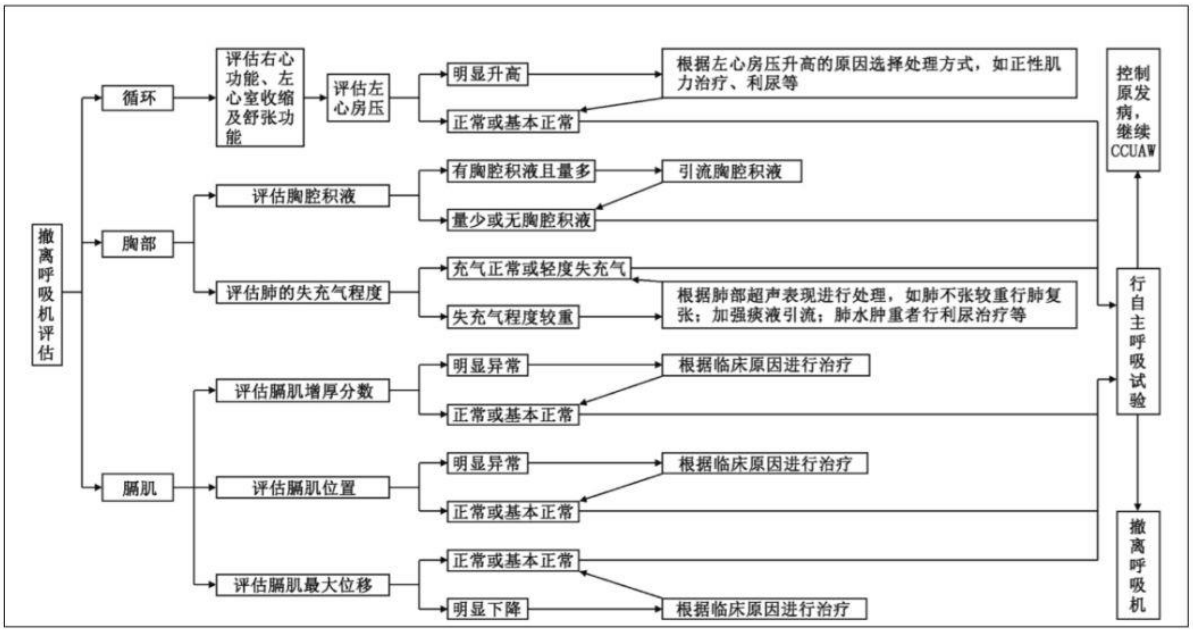


图17 新型冠状病毒肺炎机械通气患者脱机超声评估流程图

(B) the application of critical ultrasound in the circu lation management of patients with new coronavirus pneumonia

1. Monitoring and Evaluation Initial fluctuation cycle selected selection

Based on clinical evaluation, peripheral arterial catheters and central venous catheters were placed as soon as possible, continuous invasive arterial pressure and central venous pressure monitoring were performed, arteriovenous blood gas analysis and inspection were performed in time, and critical ultrasound examination was performed at the same time (Figure 18).

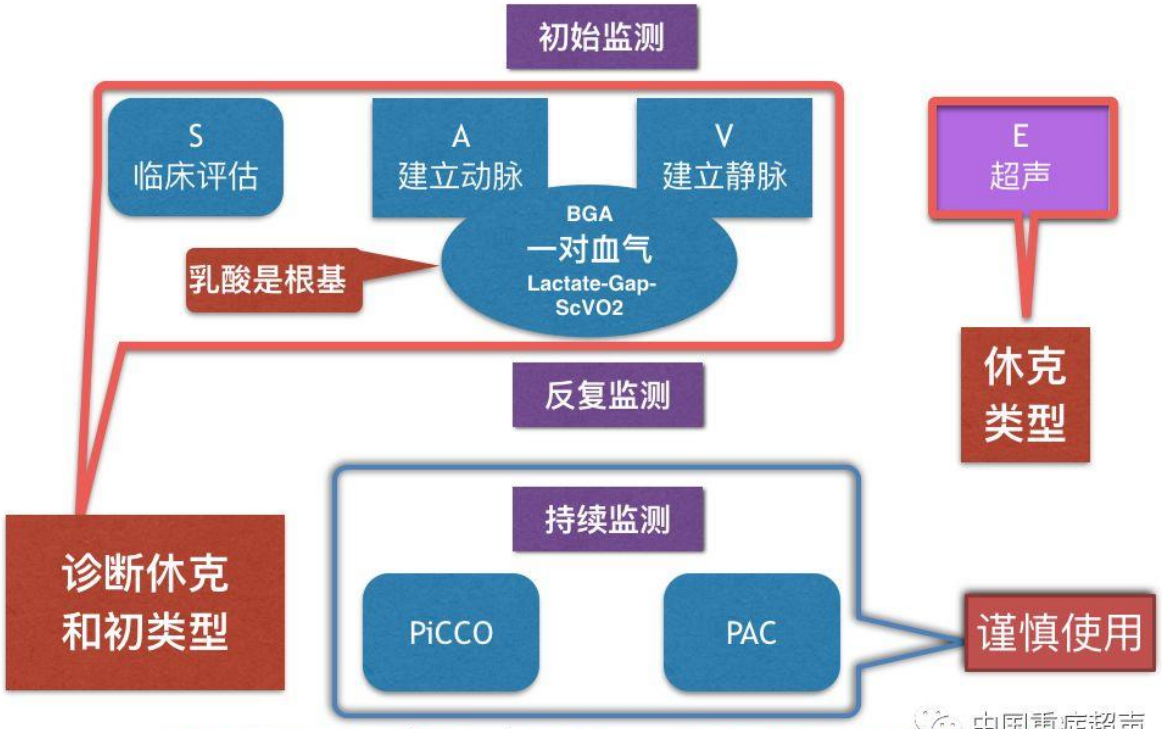


图18 新型冠状病毒肺炎患者血流动力学监测初始选择SAVE方案

2. Critical ultrasound quickly clarifies the circulation status of patients with new coronavirus pneumonia and guides circulation management

Compared with respiratory failure, the occurrence of circulatory involvement in patients with severe NCP is often considered to occur late and is not even valued. It is generally believed that rapid disease progression, large-scale consolidation, and invasive mechanical ventilation for the treatment of fatal hypoxemia are the main causes of acute pulmonary heart disease and subsequent circulation fluctuations. Myocardial damage is often associated with fluid overload, acute pulmonary heart disease, or prolonged hypoxemia.

In fact, in the early stages of severe illness, as long as hypoxia and dyspnea occur, the body will have circulatory reactions, including increased heart rate, increased myocardial contractility, and even abnormalities after stress. Volume problems are often combined at the same time, especially the foundation Diseases, such as hypertension, ischemic heart disease, chronic obstructive pulmonary disease, and senile cardiovascular changes, cyclic fluctuations are more likely to show up, but only in different stages and degrees. It is worth noting that because of the limited resources

of the ICU, many patients with sepsis or septic shock caused by inadequate infection control during hospitalization (including during the ICU stay) may be an important cause of cardiopulmonary injury and further distant organ dysfunction.

NCP's lung damage often starts from the alveolar epithelial cells, and then gradually deepens, and interstitial capillaries and endothelium are further damaged, so the images often show ground glass to severe exudation, then consolidation, and often gravity Dependence, so from the primary injury to the secondary injury, also reflects the connotation of hemodynamic changes.

Examination by cardiac ultrasound (apical four-chamber heart, parasternal long axis, parasternal short axis, sub-sacral heart, sub-sacral vena cava long and short axis planes) and lung 12-division method, according to hemodynamic diagnosis and treatment The footwork assessment path can quickly understand the patient's capacity, cardiac function, flow status, and organ perfusion, and develop a hemodynamic management plan (Table 1). When feasible, it is recommended to measure the three parameters of inferior vena cava diameter, left ventricular ejection fraction, left ventricular outflow tract velocity-time integral for continuous dynamic assessment of patient volume status and volume responsiveness, left ventricular systolic function, and accurate left ventricular output , If necessary, perform a blood flow-related ultrasound hemodynamic evaluation (Flow Related Echodynamic Evaluation, FREE) to guide patients in hemodynamic therapy: according to the hemodynamic 5P principle, that is, lower central venous pressure (lower CVP), Appropriate heart rate (optimized Pulse / HR), pump function (Pump), appropriate blood pressure (Pressure), perfusion management (Figure 19).

3. Critical ultrasound assessment of right heart function provides important information for cardiopulmonary management in patients with new coronavirus pneumonia

Patients with new type of coronavirus pneumonia may cause increased pulmonary vascular resistance due to hypoxic pulmonary vasospasm, hypercapnia, and inflammatory contractions caused by pulmonary vasoconstriction, which triggers ACP and affects right heart function. Mechanical ventilation itself, especially when lung protective

ventilation is not performed in place, will further increase pulmonary artery pressure and aggravate right heart function impairment. If there is a capacity overload situation in liquid management at the same time, the probability is higher.

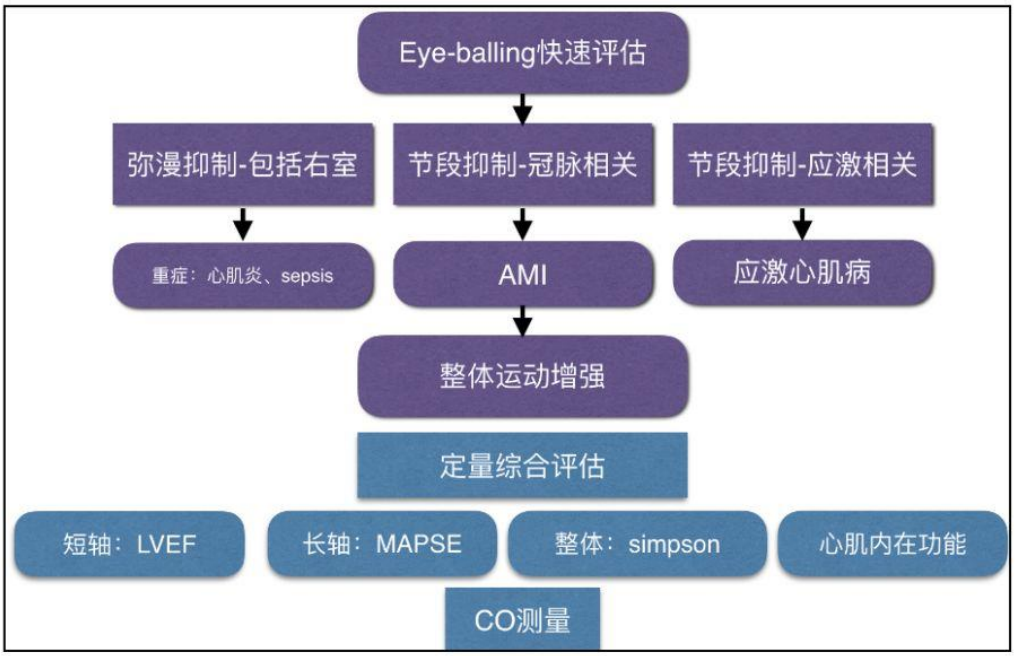
Right ventricular dysfunction has a crucial impact on circulation and respiratory management strategies. Critical ultrasound can quickly detect changes in right heart function at the bedside and analyze the cause, providing important information for cardiopulmonary management in patients with new type of coronavirus pneumonia (Figure 20). In the clinical application of critical ultrasound for evaluation, it is often necessary to combine central venous pressure monitoring, which is conducive to the timely detection and management of the occurrence and development of acute pulmonary heart disease.

4. Assessment of left ventricular function with critical ultrasound in patients new coronavirus pneumonia

From the existing experience of treating NCP patients, it is different from severe lung injury at the beginning of SARS. NCP's initial manifestations are not serious, but some patients will have rapidly worsening multiple organ failure at a later stage. The mechanism is an "inflammation" storm".

The body often experiences uncontrolled inflammatory reactions. In the case of collective abnormal reactions caused by hypoxia, respiratory distress, severe stress, inflammation, etc., the left heart often shows some characteristic manifestations: the stress segment-overall enhancement-diffusely weakened. Among them, diffuse suppression, clinically fatal hypoxemia often occur during tracheal intubation or after sudden cardiac arrest and resuscitation, prolonged hypoxia and inflammation also need to be considered. Cyclic failure after cardiac arrest should be a combination of diffuse cardiac function suppression and vascular tone reduction caused by lactic acidosis after cardiac arrest. Patients with concomitant infections or myocardial infarction will also have corresponding cardiac changes. Critical ultrasound can be used for rapid qualitative and quantitative comprehensive

assessment to evaluate the etiology and guide the treatment of patients with left ventricular systolic insufficiency (Figure 21).



注：AMI 急性心肌梗塞，LVEF 左心室射血分数 MAPSE 二尖瓣环位移 simpson 辛普森法 CO 心输出量

图21 左心室收缩功能超声评估流程

(C) Critical ultrasound helps to find out the chronic cardiopulmonary basic situation of NCP patients in time

The majority of elderly patients with severe NCP suffer from ischemic heart disease, hypertension, valvular disease in the elderly, and other basic diseases such as chronic pulmonary heart disease. Critical ultrasound is useful for assessing the underlying conditions, early warning of treatment risks, and making treatment decisions. It also helps to understand the impact of underlying diseases on the critical management of NCP patients, including acute pulmonary heart disease judgment, fluid management, and lung conditions. Ultrasound evaluation of the chronic basic condition of the heart mainly includes thin wall thickness, cardiac cavity size, and abnormal morphology. The assessment of chronic lung conditions mainly includes

changes in pleural uniformity, thickness and mobility, and homogeneity of the B line.

(D) Critical ultrasound plays an important role in the management of ECMO in patients with severe new coronavirus pneumonia

ECMO as a support method for severe respiratory failure is the last rescue treatment for patients with NCP. Patients with fatal hypoxemia that have not improved after respiratory treatments such as lung protective ventilation, muscle relaxants, prone position, and lung recruitment ECMO support should be accepted as early as possible.

Implementation of ECMO support should be established by an experienced in-vitro life support team and followed up by professional medical staff with ECMO operation and maintenance capabilities. Critical ultrasound can help judge the application indications and type selection of ECMO; guide the catheter position and monitor the flow during the catheterization in real time. Hemodynamic and pulmonary lesion assessments are performed during the treatment of ECMO to guide the timing of withdrawal. The implementation of ECMO without the concept of critical illness and the treatment of ECMO without the guidance of critical ultrasound assessment bear significant risks.

(E) Critical ultrasound helps to achieve organ management other than cardiopulmonary based on cardiopulmonary oxygen transport organs

Severe NCP patients often develop multiple organ involvement after cardiopulmonary oxygen transport organ damage. Support for organs other than cardiopulmonary is emphasized on the basis of protecting cardiopulmonary oxygen transport, recognizing the self-regulating function of the forward arterial blood flow of organ perfusion, and paying attention to the backward management of organ perfusion. Critical ultrasound can guide organ-oriented intensive management treatment programs by evaluating different organ functions and organ blood flow regulation functions (Figure 22).

(F) Critical ultrasound helps establish a treatment system for patients with severe new coronavirus pneumonia based on severity fine classification

Based on the severity classification, a rescue system covering protective ventilation, circulation protection, and oxygen consumption organ protection is an important guarantee for implementing the concept of protection as the first treatment to reduce the incidence of severe illness and mortality in NCP patients. Critical ultrasound plays an important role in the treatment system based on severe classification (Table 2).

1-2级：与急性呼吸窘迫综合征（ARDS）一致的保护性治疗，尤其机械通气患者：基于适当镇痛镇静基础上的"CVP-Pretection"保护原则，遵循右心保护。

A.基于肺保护的循环（**C**irculation）策略：维持较低的容量状态和合适的渗透压；

B.基于肺保护的通气(**V**entilation)策略：小潮气量（4-6ml/Kg）、合适的PEEP水平、低平台压（<30cmH2O）

C.俯卧位通气(**P**rone position ventilation)：对于严重ARDS患者，建议进行肺复张。在人力资源充足的情况下，每天应当进行12小时以上的俯卧位通气。

若保护性策略实施下难以达到氧输送目标，VV-ECMO；

3级：

A.精准血流动力学治疗策略：**5P+5A**

5P:灌注为目的(**P**erfusion)、心泵功能【**P**ump(CO)】、合适的血压（B**P**-MA**P**）、较低的中心静脉压（lower CV**P**）、合适的心率（optimized **P**ulse HR）

5A（Avoid）微循环保护原则:避免低灌注、避免高灌注、避免血液稀释、避免液体渗漏、避免单一血管活性药物过高剂量

B. 遵循基于右心保护的机械通气治疗策略：氧合指数＞150mmHg，PCO2<48mmHg,驱动压<18cmH_2O,合适的PEEP，俯卧位。

若5P、5A策略难以达到氧输送目标，VA-ECMO。

4级 1级、2级治疗基础上的器官功能保护策略，即保证心肺氧输送前提下的器官功能保护支持：(1)根据器官自我调节选择合适血压(2)根据器官对CVP耐受性积极推进CVP越低越好；

5级 1级、2级治疗基础上重点实施脑保护治疗策略:基于脑血流、脑氧监测以及双频脑电监测的脑保护治疗策略；

O**其他** （呼吸循环未受累、单一器官功能受损）：给予单一器官的支持治疗。

表2 基于重症超声精细重症分级的新型冠状病毒肺炎救治体系

(G) Value of critical ultrasound in the treatment of abnormal reactions in patients with severe new coronavirus pneumonia

In the course of disease development, patients with NCP often experience sudden rises in body temperature, exacerbation of breathing difficulties, obvious circulation fluctuations, and rapid deterioration of other organ functions. Most experts believe that under the interaction of the virus and the body, hypoxia and dyspnea further aggravate the body's unequal response to inflammation and various other malignant stimuli.

It is important to correct hypoxemia, inhibit abnormal body reactions, and use target body temperature management, analgesia and sedation, anti-stress, and anti-inflammatory reactions. At the same time, it is important to reduce metabolism to achieve organ protection and treatment. In the abnormal response of the body caused by factors such as inflammation, the age-related characteristics deserve attention. Non-elderly patients usually have a strong initial stress response, a significant compensatory response, severe microcirculation damage, and early organ damage, especially prominent lung damage and cardiovascular function. Elderly patients have more basic diseases, aging of cardiovascular function, insufficient immune stress response, insufficient compensatory response of the body, milder early severe symptoms, less damage to initial organ function, often cover the disease progression, and can suddenly appear as circulatory collapse Fatalities need special attention. Critical ultrasound is helpful for early detection of abnormal organ changes, and indirectly assesses the intensity of inflammatory response and treatment effect.

(H) Critical ultrasound helps to clarify the treatment goals for patients with severe new coronavirus pneumonia

The goals of the diagnosis and treatment plan are clear. Reducing fluctuations reduces unnecessary contact, which is of great significance for medical care work in special environments. The goals of the diagnosis and treatment planning process are clear. The proportion of emergencies in NCP patients is reduced, and the maximum risk is reduced by reducing rescue.

(I) Critical ultrasound implementation process based on the treatment system for patients with severe new coronavirus pneumonia

NCP patients admitted to the ICU are very critically ill, and the protection needs of medical staff are very strict. In this special scene, critical ultrasound can give full play to the advantages of simple operation, no transport, easy protection, and rapid and complete evaluation of organ function, especially respiratory and hemodynamic evaluation.

During the treatment of severe NCP patients after admission to the ICU, they must follow the principle of the implementation of the process of critical ultrasound, including the operation process and evaluation path. Emphasis on multi-organ evaluation based on cardiopulmonary assessment, including comprehensive evaluation from structure to blood flow and function.

The main applications of critical ultrasound procedures include:

1. Based on the modified version of the A-CCUE rapid process-if necessary, the cyclic heart assessment section uses the FREE process

Patients with respiratory cycle fluctuations can implement a modified version of the A-CCUE fast process operation procedure based on the problem-oriented basis, and add quantitative evaluation of key parameters to the six-step hemodynamic evaluation method; if the problem cannot be solved, you can Increasing the evaluation section and measurement, such as adding the inferior vena cava short-axis section, the parasternal right ventricular inflow channel section, and the main pulmonary artery long-axis section, etc., using a blood flow-related ultrasound hemodynamic evaluation process (FREE, Figure 23) Evaluation.

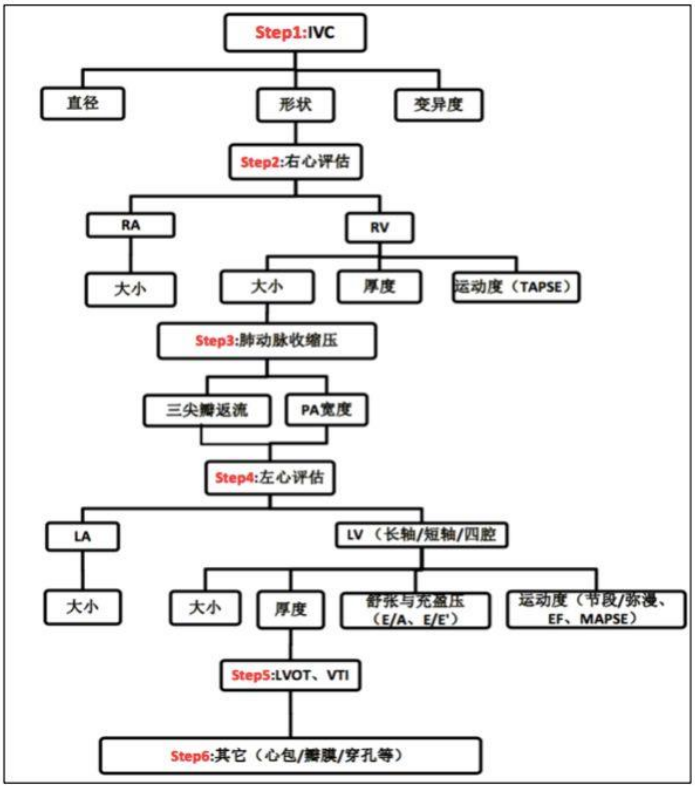


图23 血流相关的超声血流动力学评估流程（Flow Related Echodynamic Evaluation protocol，FREE protocol）

2. Pulmonary ultrasound 8/12 partition method, if necessary, 28 partitions for continuous semi-quantitative scoring

When the lung assessment using the 8/12 subdivision method cannot completely complete the assessment of the needs, especially the critically ill patients with a B-mode distribution, a comprehensive semi-quantitative method can be used, the 28 subdivision method can be used with caution (Figure 24).

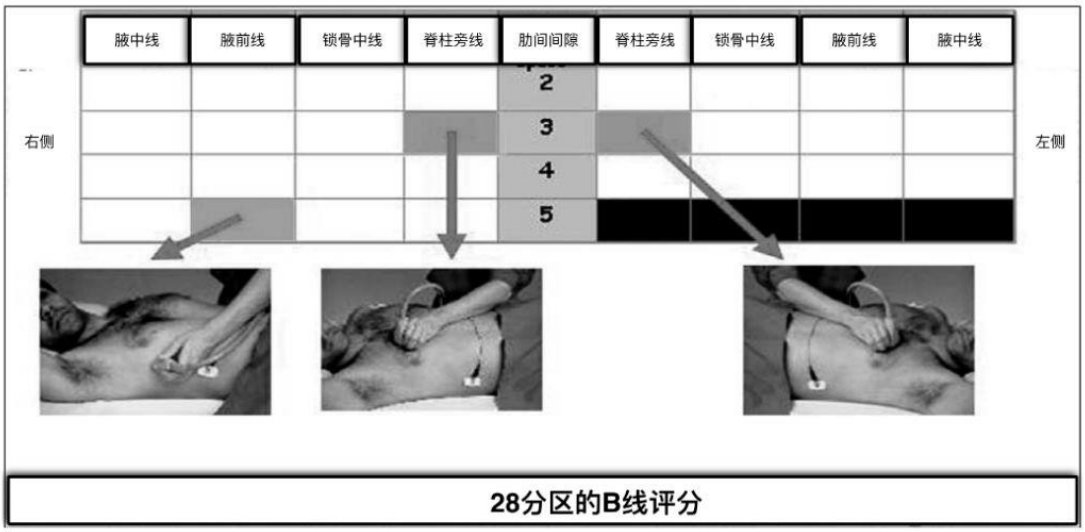


图24 肺部超声28分区法

3. Special ultrasound evaluation of cardiopulmonary function

When patients have organ damage other than cardiopulmonary, it appears either alone, or in combination, or almost simultaneously with cardiopulmonary injury. Ultrasound evaluation of organs is needed, and the corresponding procedures and evaluation paths for kidney, gastrointestinal, and cranial brain evaluation are detailed in CCUSG's Technical Specifications for Clinical Application of Critical ultrasound.

6 Critical ultrasound helps to improve the success rate of related techniques in patients with severe new coronavirus pneumonia

When medical personnel treat patients with new type of coronavirus pneumonia, because the disease is highly contagious, secondary or even tertiary protection is required. Under special scenarios with heavy protective clothing and goggles, any operation includes the daily relatively simple peripheral veins. Both puncture and blood collection are very difficult. And easy to cause infection. For this reason, whether it is a central venous catheter, an arterial catheter, a peripheral venipuncture, a venous blood collection, or a gastrointestinal tube placement, it is recommended that

critical ultrasound be used when possible to help improve the success rate of puncture and reduce the operation time.

7 Critical ultrasound helps improve the safety and quality of care for patients with severe new coronavirus pneumonia

The role of intensive care in the treatment of patients with severe NCP is unquestionable. This type of critically ill patients has a huge amount of intensive care-related care, and at the same time has very high requirements for nursing treatment and safety. In addition to the central venous catheterization, arterial catheterization, peripheral venipuncture, and venous blood collection as described above, intensive care related to airway management, chest physical therapy, intestinal function management, skin management, etc. Management is essential to help improve the safety and quality of care.

8 Prevention and Control of Ultrasound Infection in Patients with New Coronavirus Pneumonia

1. Protection standard for medical staff during ultrasound examination

When the ultrasound of the heart, lungs, blood vessels or other organs is simply performed, there is no obvious close-range droplets and blood in contact with the environment, according to the three-level protection standard, that is, disposable work caps, protective glasses (anti-fog type) or protective faces , Medical protective mask (N95), disposable protective clothing, disposable latex gloves, disposable shoe covers, quick-drying hand disinfectant (75% ethanol) equipped with substances. If there is a risk of discharge of secretions or pollutants on the medical personnel and the face, use comprehensive respirator protection.

2. Disinfection of ultrasound machines

Ultrasound machines are used exclusively in the ward of confirmed patients. Before and after use, disinfect the host, including the casing and display. Wipe off and disinfect with 75% medical alcohol in the off state. Be careful to prevent the disinfectant from flowing into the gap of the control panel. Ultrasonic machine can be sterilized by low-frequency ultraviolet rays (once a week). The use of quaternary ammonium disinfectants is prohibited, which may easily cause damage to the casing. Ultrasound probes for body surface disinfection are recommended to be disinfected with disinfectants containing quaternary ammonium salts or hydrogen peroxide.

3. Special ICU related prevention and control establishment in ICU

(1) Implement strictly in accordance with nationally required prevention and control measures (see related regulations), follow the key principles of protection first, seal when worn, put out dirt when taking off, and wash after taking off.

(2) ICU basic nosocomial infection measures: according to relevant regulations.

9 The value of telemedicine and artificial intelligence in the treatment of patients with severe new coronavirus pneumonia

Multipoint remote based on complete bedside information and intelligent prospective analysis based on granular data are of great significance for patients with severe NCP. Severe patients have complex conditions and progress rapidly. The accuracy and timeliness of clinical treatment decisions are extremely high. Therefore, integrating multi-modal information through clinical information systems, cleaning and combing to achieve visual presentation, based on big data and mechanical learning, using artificial intelligence to reduce the decision-making pressure of clinical medical staff has a strong practical effect.

1. Multi-point telemedicine service based on complete information at the bedside of critically ill patients

More importantly, the large-scale and rapid outbreak of the new coronavirus pneumonia epidemic has led to severe shortages of medical staff in critical care and very different treatment capabilities. Therefore, expert guidance or normative guidance in the field of critical medicine is extremely important, and improving the efficiency of expert guidance through telemedicine has become an inevitable choice.

The consensus of the American Telemedicine Alliance in 2007 pointed out that if a network system between ICUs is established, the work efficiency of the entire intensive care system will be greatly improved, so that traditionally an ICU doctor can only manage one patient and change to manage 50 to 100 patients with severe illness. This means that the team of experts can play a greater efficiency, which also necessarily means that more critically ill patients can get better treatment.

As the core basis of clinical judgment and treatment, the standardized and reliable acquisition of disease information by on-site medical staff has become the first influencing factor for the success of critical care. Because patients with new coronavirus pneumonia are highly infectious, medical staff must perform secondary or even tertiary protection. Heavy protective clothing and goggles directly limit the feasibility of obtaining disease information such as traditional auscultation.

Therefore, the construction of a long-range mobile critical medical network system with visualization, touching, listening, listening and visualization with critical ultrasound as the core has become the core content and technical means of medical service model innovation. Realize on-site medical behavior guidance and quality control through interactive electronic processes; real-time sharing of on-site audio and video, visual inspection, monitoring and auxiliary inspection information with remote experts, and real-time supervision of the emergency site, transfer and in-hospital patient treatment

can be greatly realized Improve the accuracy and rescue efficiency of NCP in critical care.

2. Artificial intelligence based on multi-modal clinical data to assist in early warning of severe events and clinical decision-making

ICU collects a large amount of patient data, including monitoring equipment data, such as ECG monitors, respiratory monitoring, hemodynamic monitoring, cerebral oxygen saturation and other organ function monitoring; life support equipment data, such as ventilators, blood purification treatment instruments and ECMO, etc .; a large number of image monitoring data, including audio and video images represented by monitoring information for critical ultrasound assessment; patient medical record data and other inspection data. This seems to establish a strict data support system for the treatment of critically ill patients.

However, the rapid increase in the amount of medical data has put tremendous pressure on clinical medical staff. These multi-dimensional and complex data often require effective analysis by senior physicians with years of clinical experience, before a relatively reliable diagnosis and treatment strategy can be derived. In clinical practice, due to the relative lack of experience and the large amount of monitoring data, even an excellent clinician can hardly formulate an optimal diagnosis and treatment plan for each patient in a short time. Therefore, the use of artificial intelligence technology to carry out data mining, prognosis prediction, event warning and auxiliary decision-making, reduce the workload of physicians, and propose better NCP diagnosis and treatment programs are clinical needs and research directions.

10 Limitations of treatment and recommendations

This treatment recommendation has the following limitations First, time is short and all clinical issues cannot be fully considered. Second, this treatment recommendation is mainly based on the previous experience of critical ultrasound in the diagnosis and treatment of viral pneumonia and the existing expert experience in the treatment of new coronavirus pneumonia, so it may need to be revised.

Writing expert

Zhang Lina (Department of Critical Care Medicine, Xiangya Hospital, Central South University), Yin Wanhong (Department of Critical Care Medicine , West China Hospital, Sichuan University), He Wei (Department of Critical Care Medicine, Beijing Tongren Hospital, Capital Medical University), Zhang Hongmin (Department of Critical Care Medicine, Peking Union Medical College), Liu Lixia (Affiliated to Hebei Medical University) Department of Intensive Medicine, Fourth Hospital), Zhu Ran (Department of Intensive Medicine, First Affiliated Hospital of China Medical University), Wu Jun (Department of Intensive Medicine, Ruijin Hospital, Shanghai Jiaotong University), Cai Shuhan (Department of Intensive Medicine, Zhongnan Hospital of Wuhan University), Xi Yangong (Affiliated Hua of Tsinghua University, Letter Hospital), Wang Xiaoting (Peking Union Medical College Hospital Tibet Autonomous Region People's Hospital Group Assistance to Tibet/Doctoral Team)

Participating experts

Duan Jun (Department of Critical Care Medicine, China-Japan Friendship Hospital), Shang Xiuling (Department of Critical Care Medicine, Fujian Provincial Hospital), Ai Shanmu (Department of Critical Care Medicine, Army Characteristic Medical Center), Xu Qianghong (Department of Critical Care Medicine, Zhejiang Hospital), Lu Liwen (Department of Emergency Medicine, People's Hospital of Guangxi Autonomous Region), Chen Wenjin (ICU, Beijing Xuanwu Hospital, Capital Medical University), Liu Haitao (Department of Critical Medicine, Harbin Medical University Cancer Hospital), Ren Hong (Department of Critical Medicine, Shanghai Children's Medical Center), Zhu Ying (Department of Critical Medicine, Hangzhou First People's Hospital), Zhu Weihua (Department of Critical Care Medicine, Second Affiliated Hospital of Kunming Medical University), Qian Zhaoxin, Liu Zhiyong, Ma Xinhua, Zhao Chunguang, Cao Lan, Sun Yang (Xiangya Hospital of Central South University), Chai Wenzhao, Zhao Huading, Xin Chen, Huan Zhang, Qing (Peking Union Medical College Hospital), Liu Jinglun (First Affiliated Hospital of Chongqing Medical University, Department of Intensive Medicine), Cui Song (Dalian Central Hospital), Fang Wei (Department of Intensive Medicine, Affiliated Hospital of Qingdao University), Wu Jianfeng, Si Xiang (Department of Intensive Medicine, First Affiliated Hospital of Sun Yat-sen University,) Xu Jingqing, Li Min, Lu Shenlei (Intensive Medicine, Fujian Provincial Hospital), Yang Jiangang (No. 3 in Datong City) Department of Critical Care Medicine, People's Hospital), Hu Bo, Li Lu, Yang Xiao, Qin Aihua, Jia Bentao, Dong Jiang (Department of Critical Care Medicine, Central South Hospital of Wuhan University), Ding Renxuan (Department of Critical Care Medicine, First Affiliated

Hospital of China Medical University), Wang Changsong (Oncology Hospital, Harbin Medical University) Medical Department), Liu Ling (Zhongda Hospital Affiliated to Southeast University), Shang Youyuyuan (Affiliated Union Hospital of Huazhong University of Science and Technology)

Review Expert

Liu Dawei (Peking Union Medical College Hospital), Guan Xiangdong (First Affiliated Hospital of Sun Yat-sen University), Qiu Haibo (Zhongda Hospital Affiliated to Southeast University), Chen Dechang (Ruijin Hospital Affiliated to Shanghai Jiaotong University), Ai Yuhang (Xiangya Hospital of Central South University), Kang Yan (Western China Hospital of University of Sichuan), Ma Xiaochun (The First Affiliated Hospital of China Medical University), Yan Jing (Zhejiang Hospital), Hu Zhenjie (The Fourth Affiliated Hospital of Hebei Medical University), Yu Kaijiang (the First Affiliated Hospital of Harbin Medical University), Li Jianguo (Wuhan University Central South Hospital), Li Weiqin (East China Theater General Hospital), Zhou Fachun (The First Affiliated Hospital of Chongqing Medical University)

Expert group of Hubei anti-epidemic work unit

Member of the Expert Group of the National Health and Health Committee (Qiu Haibo, Guan Xiangdong), West Hospital of Union Hospital, Huazhong University of Science and Technology (Qian Zhaoxin, Zhang Lina, He Wei, Liu Zhiyong, Ma Xinhua, Zhao Chunguang, Cao Lan, Sun Yang) Li Weiqin Ai Shanmu) Tongji Hospital Affiliated to Huazhong University of Science and Technology (Tongji Hospital, Zhang Hongmin, Duan Jun, Ding Xin, Zhao Hua, Chen Huan) East Hospital of Wuhan University People's Hospital (Kang Yan, Zhou Fachun, Ding Renhua), Wuhan University Central South Hospital Yang Xiao, Qin Aihua) Wuhan Jinyintan Hospital (Chen Dechang, Shang Xiuling, Xu Jingqing, Lu Shen, Lei Shangyou, Yu Yuan) Tongji Hospital, Huazhong University of Science and Technology (Fang Wei), Wuhan Hankou Hospital (Wu Jianfeng, Xiang Xiang), Wuhan Union Medical College Red Cross Hospital (Yin Wanhong) Oncology Department of Union Hospital Affiliated to Huazhong University of Science and Technology (Li Min) Hubei Xiaogan Central Hospital (Liu Jinglun) Xiantao People's Hospital of Hubei Province (Yang Jiangang)

Modified on 2020-02-19