Journal of Pharmaceutical Research International

33(56B): 55-61, 2021; Article no.JPRI.78708
ISSN: 2456-9119
(Past name: British Journal of Pharmaceutical Research, Past ISSN: 2231-2919, NLM ID: 101631759)

Imagining of Acute Respiratory Distress Syndrome: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2021/v33i56B33926

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/78708

Review Article

Received 06 September 2021
Accepted 12 December 2021
Published 13 December 2021

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ABSTRACT

Acute respiratory distress syndrome (ARDS) is a life-threatening disorder marked by low oxygen levels and rigid or non-compliant lungs. In the absence of any indication of cardiogenic pulmonary edema, ARDS is defined as an acute disease that begins within 7 days of the triggering event and is marked by bilateral lung infiltrates and severe progressive hypoxemia. ARDS has a significant death rate, and there are few effective treatment options for this life-threatening illness. The management of these severely ill patients in the intensive care unit relies heavily on imaging. Chest radiography, bedside lung ultrasonography, and computed tomography scans can all help with patient care and prognostic variables identification. However, imaging results are not always specific, and other diagnosis should be considered.

Keywords: Respiratory distress; pulmonary edema; ARDS; hypoxemia.

1. INTRODUCTION

Acute respiratory distress syndrome (ARDS) is a life-threatening disorder marked by low oxygen levels and rigid or non-compliant lungs. Capillary endothelial injury and widespread alveolar damage are linked to the condition. Patients with ARDS frequently have various degrees of pulmonary artery vasoconstriction and may develop pulmonary hypertension as a result. ARDS has a significant death rate, and there are few effective treatment options for this life-threatening illness [1]. The use of chest radiography and computed tomography (CT) in the diagnosis and management of acute respiratory distress syndrome is critical. The presence of pulmonary opacification on the chest radiograph is required for the diagnosis of ARDS, whereas CT is useful not only in the diagnosis of ARDS but also in the detection of sequelae [2].

In the absence of any indication of cardiogenic pulmonary edema, ARDS is defined as an acute disease that begins within 7 days of the triggering event and is marked by bilateral lung infiltrates and severe progressive hypoxemia. The proportion of oxygen in the patient's arterial blood (PaO2) to the %age of oxygen in the inspired air defines ARDS. The PaO2/FiO2 ratio in these individuals is less than 300. The ARDS definition was modified in 2012 and is now known as the Berlin definition. It differs from the previous American European Consensus definition in that it does not include the term Acute Lung Injury; it also eliminates the wedge pressure requirement (less than 18) and adds the requirement of positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) of greater than or equal to 5 mm Hg [1]. Despite being diagnosed 50 years ago, this illness remains at the heart of scientific controversy, both because of its complicated pathophysiology and because of the disagreement over possible treatments [3,4].

Although the radiology of ARDS is distinct, COVID19 pneumonia appears to have distinct features. This is most likely due to the coexistence of viral pneumonia and ARDS, and it enables radiologists to be fairly specific in diagnosing COVID19 pneumonia. When comparing COVID19 pneumonia in China to viral pneumonia in the United States, the most distinguishing features included a peripheral distribution of opacification, frosted glass opacities, and vascular thickening or enlargement [5].

These imaging features appear to be typical of COVID19 pneumonia and can aid in the early screening of highly suspected cases as well as the assessment of disease severity and extent. Lesions in COVID19 lung disease are more likely to be bilateral, lower lung predominant, and multifocal as the disease progresses. They frequently have the appearance of rounded opacities, which are referred to as "COVID balls." The extent of lung involvement increases as ARDS progresses, and there is a consolidative component [5].
The importance of imaging in the detection and management of ARDS may be shown in the fact that it has always been utilized to characterize its existence since its discovery. Electrical impedance tomography (EIT) was examined by Putensen et al. during cardiopulmonary monitoring. This fascinating overview covers everything from the method's basic foundation through picture reconstruction and analysis [3,6,7].

The clinical characteristics, etiology, and radiographic presentations of ARDS and ALI are

similar. When the PaO2/FIO2 ratio is less than 200 mm Hg, as compared to 300 mm Hg in ALI, the condition is referred to as ARDS. In this view, everyone with ARDS has ALI, but not everyone with ALI has ARDS. The presence of bilateral infiltrates on the chest radiograph is required for both ARDS and ALI to be diagnosed [2].

The epidemiology, etiology, and pathophysiology of ARDS have all progressed significantly in the last 50 years. Furthermore, randomized trials to enhance mechanical ventilation and fluid treatment for ARDS patients have shown better clinical results. Despite significant advances in improving supportive treatment for ARDS, no viable pharmaceutical medicines for the disease have yet been developed. However, ARDS is rapidly being recognized as a heterogeneous illness, prompting efforts to find clinical and molecular characteristics that might be used to divide individuals into sub phenotypes that may respond better to certain medications [8].

2. ETIOLOGY

There are several risk factors for ARDS. Extrapulmonary origins include sepsis, trauma, large transfusion, drowning, drug overdose, fat embolism, inhalation of toxic gases, and pancreatitis, in addition to pulmonary infection or aspiration. Extra thoracic infections and/or injuries set off an inflammatory cascade that leads to pulmonary damage. The Lung Injury Prevention Score can assist identify individuals who are at low risk for lung injury, but a high score is less useful.

The following are some ARDS risk factors [1]:

- Elderly
- Gender: female
- Using alcohol and smoking
- Vascular surgery of the aorta
- Surgery for the heart and blood vessels
- Traumatic brain injury (TBI)

The use of computed tomography has offered fresh insights into the pathophysiology of ARDS, indicating that ARDS does not impact the lung parenchyma uniformly and that the degree of lung injury in the ARDS population is widely dispersed. Positron emission tomography (PET) is a type of functional imaging that adds incremental information to morphological imaging. Regional perfusion, ventilation, aeration, lung vascular permeability, edema, and inflammation can all be measured. Lung ultrasonography and EIT are noninvasive, radiation-free technologies that may be used at the bedside. When x-rays or CT scans are unavailable, lung ultrasonography can give important information for ARDS diagnosis [9].

3. EPIDEMIOLOGY

The incidence of ARDS in the United States is estimated to be between 64.2 and 78.9 cases per 100,000 person-years. ARDS patients are originally classed as mild in 25% of cases and moderate or severe in 75% of cases. A third of mild cases, on the other hand, develop to moderate or severe illness. According to an assessment of the literature, mortality decreased by 1.1% each year from 1994 to 2006. The total pooled death rate for all of the trials examined, however, was 43%. The fatality rate of ARDS is proportional to the severity of the disease; for mild, moderate, and severe disease, the rates are 27%, 32%, and 45%, respectively [1,10-13].

ARDS is predicted to affect 5–20% of all mechanically ventilated ICU patients. Despite advances in ARDS care, such as the adoption of lung protective breathing methods, severe ARDS mortality remains high. There are presently no useful biomarkers or pharmaceutical targets to use in ARDS patients to track illness progression [13].

4. PATHOPHYSIOLOGY

ARDS has been linked to neutrophil-mediated pulmonary inflammation and abnormal vascular permeability in previous investigations. Collagen breakdown product proline-glycine-proline (PGP) has a structural similarity to ELR+ chemokines like CXCL8 and activates the CXCR1/2 pathway, boosting neutrophil chemotaxis. In addition, CXCR2 activation causes vascular permeability to increase. PGP and its acetylated form (Ac-PGP) (referred to as PGP peptides) have been linked to a number of chronic inflammatory lung disorders, including COPD and cystic fibrosis (CF) [13].

ARDS goes through many stages, beginning with alveolar-capillary destruction, progressing to a proliferative phase marked by increased lung function and repair, and finally to a fibrotic phase that signals the completion of the acute illness process. Inflammation, apoptosis, necrosis, and enhanced alveolar-capillary permeability define pulmonary epithelial and endothelial cellular injury, which leads to alveolar edema and proteinosis. As a result of the alveolar edema, gas exchange is reduced, resulting in hypoxemia [1].

Increased neutrophilic infiltration and capillary leakage define ARDS, leading in the accumulation of protein-rich inflammatory fluid of the lungs. When the extracellular matrix is disrupted following an injury, proinflammatory chemokines are released, which can trigger neutrophil transmigration to the injury site. Neutrophils release matrix-degrading enzymes like MMP-8 and MMP-9 during this process. Alkali hydrolysis or proteolytic digestion of ECM protein by MMP-8 and -9 has been demonstrated to result in peptide fragments that are cleaved by prolyl endopeptidase to produce PGP peptides. Prolyl endopeptidase released from neutrophils can then generate PGP peptides independently of the CXCL8 pathway, greatly boosting the inflammatory cascade [13].

5. PLAIN CHEST RADIOGRAPHY

The plain chest radiograph is a useful diagnostic for confirming diagnoses, confirming the placement of tubes and lines, monitoring lung disease progression, and detecting problems in ARDS. The basic radiographic appearances of ARDS vary according on the stage of the illness, but regardless of the etiology, these characteristics are frequently stereotypical.

Chest x-ray characteristics of proteinaceous interstitial oedema appear 12-24 hours after the first lung damage. Within a week, alveolar pulmonary oedema (hyaline membrane) develops as a result of type 1 pneumocyte destruction [14].

Acute Phase (up to first 7 Days): In the first 24 hours after the first insult that produces ARDS, there is generally a radiographic latent phase, and the chest radiograph is commonly normal. The only exception is if ARDS is caused by direct lung damage (such as pneumonia), in which case consolidation may occur. In the next 24–72 hours, the condition rapidly deteriorates. Increased capillary permeability and the flow of protein-rich fluid into the alveolar space and interstitial result from endothelium injury, which promotes pulmonary edema. On a chest radiograph, air space and interstitial opacities in ARDS are generally bilateral and symmetrical [2].

acute respiratory distress syndrome has non-specific chest radiography abnormalities that resemble pulmonary oedema or pulmonary hemorrhage. There are diffuse bilateral coalescent opacities (the only radiological criterion defined by the Consensus Conference). The progression of ARDS can help differentiate it from simple pulmonary oedema [14].

Intermediate Phase (from the 8th to 14th day): The appearances normally stabilize and remain static for a varying amount of time after the fast onset of radiographic alterations in the acute phase of ARDS. On a chest radiograph during the intermediate period, diffuse coarse reticular opacities may appear, but this does not indicate permanent fibrosis because the opacities may resolve. New air space opacities are likely to signify superadded infection or other problems outside of the usual course of ARDS, therefore it's crucial to be alert of this stable interval in the disease's radiographic presentations [2].

Late Phase (15th day and beyond): Most radiographic abnormalities begin to resolve in the late stages of ARDS if the patient survives the acute phase. Recovery time and speed are both dependent on a variety of circumstances, including comorbidities. Indeed, the final phase of the chest radiograph might range from entirely normal to extensive coarse reticular opacities.

6. COMPUTED TOMOGRAPHY

Since the first description of the CT characteristics of ARDS, the use of CT in ARDS has grown in popularity for both clinical and scientific objectives. CT has been demonstrated to be useful not only as a confirmatory and problem-solving method, but also for identifying and prognosticating ARDS in recent research. Of course, the clinical benefits of CT imaging must be balanced against the logistics and hazards of moving a patient from the intensive care unit to the radiology department.

The Early Phase:

- Pulmonary opacification: shows an anteroposterior density gradient in the lung, with dense consolidation in the most dependent parts, melting into a backdrop of extensive ground-glass attenuation, and then normal or hyperexpanded lung in the non-dependent regions.
- Extrapulmonary ARDS is more likely to appear with bilateral symmetrical alterations on CT, whereas pulmonary ARDS is more likely to present with asymmetrical opacities.
- Ground-glass opacification is a non-specific symptom that indicates a decrease in the air content of the afflicted lung.

Oedema and protein inside the interstitial and alveolar spaces, as well as bronchial dilatation within regions of ground-glass opacification, are likely to be present in acute ARDS.
- Pneumocysts in the early stages were reported in several publications [14],

The increased weight of the overlaying lung generates compressive atelectasis posteriorly, resulting in thick opacification, according to the idea underlying the inhomogeneity of appearances in ARDS. The notion is backed by the fact that when a patient with ARDS is moved from a supine to a prone posture, the density gradient immediately redistributes [2].

Late phase: In this period, CT appearances might vary

- Complete resolution: in some cases.
- The front (non-dependent) region of the lungs has a coarse reticular pattern and ground-glass opacification, which are regarded typical late stage CT presentations.
- reticular opacification and ground-glass opacification.
- bullae and pulmonary cysts of various sizes (probably develop as a result of prolonged ventilation) [2].

In ARDS patients, a CT scan, even with decreased x-ray exposure, performed under typical settings at PEEP 5 cmH2O, may help diagnosis unexpected findings and guide the selection of suitable respiratory therapy. Even a visual examination of a conventional CT scan allows for the assessment of the amount and distribution of densities, as well as the detection of pleural effusions or localized tension pneumothoraxes that are not visible on standard x-rays [14].

A more recent study found that ARDS survivors have a less traditional illness distribution. At 6 months follow-up, Masclans et al discovered that 76% of patients exhibited abnormalities on high-resolution CT, which were generally regions of reticular and ground-glass opacification. The majority of patients, on the other hand, exhibited a widespread distribution of illness, with just about a third exhibiting the more characteristic purely anterior alterations. A lesser %age of people (18%) were found to have just posterior anomalies. The study also confirmed that airways illness (presumptive traction bronchiectasis) was frequent, meaning that these individuals had underlying lung fibrosis [9,15-17].

A second CT scan at 45 cmH2O airway pressure can be used to determine lung healing. As a result, even a visual assessment can reveal significant information about the degree of edema and lung healing, which are the anatomical and physiological foundations for PEEP selection. However, quantitative CT scan analysis allows one to determine the lung weight, the % ages of tissue open and closed to breathing, the amount of tissue that can be recruited, and the distribution of stress risers. This knowledge might help to rationalize the usage of PEEP levels and the prone posture [9].

7. LITERATURE OVERVIEW

Scaramuzzo et al. investigated an alternative imaging approach. Their research focuses on defining lung behavior in a rabbit model of ARDS when decremental PEEP is used. The imaging technology employed in this case is synchrotron radiation computed tomography (SRCT), which provides the best attainable resolution for in vivo tomographic approaches. The study found that a loss in lung capacity was linked to a reduction in both the dimension and number of airspaces in their model, however the dimensional reduction was the more important mechanism [3,18].

In a study that was Validating Measures of Disease Severity of ARDS: 125 (37%) of 340 ARDS patients died during hospitalization, and 36 (10.6%) had the ARDS-specific result, including one who underwent ECMO. Although other ARDS severity measures performed similarly, the RALE score exhibited the strongest discrimination of the ARDS-specific outcome among the five separate ARDS severity measures. Their ability to distinguish overall mortality, however, was limited. The Acute Physiology and Chronic Health Evaluation IV score, on the other hand, was the best at discriminating overall mortality but not the ARDS-specific outcome. In conclusion: While most ARDS severity assessments failed to predict hospital mortality, they did a better job of predicting death due to severe pulmonary dysfunction or the requirement for ECMO. This outcome was best discriminated by an unique composite score [12].

There is a non-specific but widespread exudation of oedema and inflammatory fluid into the lungs in individuals with acute respiratory distress

syndrome (ARDS). The clinical ramifications (dyspnoea, refractory hypoxia, decreased pulmonary compliance, and widespread pulmonary infiltrates) are devastating and are usually associated with a dismal prognosis. The management of these severely ill patients in the intensive care unit relies heavily on imaging [19]. Chest radiography, bedside lung ultrasonography, and computed tomography scans can all help with patient care and prognostic variables identification. However, imaging results are not always specific, and a variety of diagnosis should be considered [20].

8. CONCLUSION

There's no doubt that acute respiratory distress syndrome (ARDS) is a life-threatening and serious disorder. So far there's no specific pharmacological treatment of such syndrome, and management relies heavily on imaging. Chest radiography, lung ultrasonography, computed tomography scans can all help with the diagnosis and care. However, imaging results are not specific and overlap with other disorders so should be taken into consideration.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.1183/09059180.00001314
PMID: 25445951.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/78708