



Interdisciplinary Management of Acute Respiratory Distress Syndrome: Collaborative Roles of Pharmacists, Nurses, and Radiologists in Optimizing Patient Outcomes

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Abstract

Background: Acute Respiratory Distress Syndrome (ARDS) is a life-threatening condition characterized by rapid-onset, diffuse inflammatory lung injury, leading to severe hypoxemia, bilateral pulmonary infiltrates, and reduced lung compliance. It arises from diverse pulmonary or systemic insults and progresses through exudative, proliferative, and fibrotic phases, resulting in significant mortality and long-term morbidity.

Aim: This article comprehensively reviews the pathophysiology, diagnosis, and, primarily, the interdisciplinary management of ARDS. It aims to detail evidence-based supportive strategies and the collaborative roles of the healthcare team in optimizing patient outcomes.

Methods: A detailed review of ARDS was conducted, encompassing its etiology, epidemiology, and histopathology. The core management strategies analyzed are centered on lung-protective mechanical ventilation—using low tidal volumes and limiting plateau pressure—supplemented by adjunctive therapies and systematic supportive care.

Results: The cornerstone of ARDS management is lung-protective ventilation, which improves survival. Key adjuncts include prone positioning for severe hypoxemia and a conservative fluid strategy after initial resuscitation. While rescue therapies like extracorporeal membrane oxygenation (ECMO) are available for refractory cases, they require careful patient selection. Pharmacologic therapies, notably corticosteroids, have a limited and nuanced role. A coordinated, interprofessional approach is critical to implement these strategies effectively and prevent complications.

Conclusion: ARDS management is fundamentally supportive, focusing on preventing further lung injury while allowing for healing. Outcomes are optimized through the strict application of a lung-protective ventilation bundle, timely adjunctive therapies, and meticulous interdisciplinary care to manage complications and support recovery.

Keywords: Acute Respiratory Distress Syndrome, ARDS, Lung-Protective Ventilation, Prone Positioning, Interdisciplinary Care, Critical Care, Mechanical Ventilation, Outcomes..

1. Introduction

Acute respiratory distress syndrome (ARDS) is an acute, diffuse, inflammatory form of lung injury and a life-threatening condition in critically ill patients, marked by severe impairment of oxygenation, bilateral pulmonary infiltrates, and an abrupt clinical onset [1]. At the microscopic level, ARDS reflects widespread injury to the alveolar-capillary barrier, with endothelial disruption and diffuse alveolar damage precipitating increased

permeability, interstitial and alveolar edema, and protein-rich exudation into the airspaces [2]. Surfactant dysfunction, hyaline membrane formation, and alveolar collapse compound ventilation-perfusion mismatch and shunt physiology, producing refractory hypoxemia that is often disproportionate to radiographic findings. Clinically, these processes translate into reduced lung compliance, heightened work of breathing, and a characteristic need for escalating ventilatory support in the appropriate

clinical context [1]. Operationally, ARDS is a syndrome that begins within seven days of a known clinical insult—such as pneumonia, sepsis, aspiration, trauma, or transfusion—and is defined by bilateral opacities on chest radiograph or computed tomography that cannot be fully explained by cardiac failure or fluid overload [2]. The Berlin definition codifies these criteria and further specifies oxygenation thresholds using the ratio of arterial oxygen tension to inspired oxygen fraction ($\text{PaO}_2/\text{FiO}_2$), with a threshold of less than 300 mm Hg under conditions of applied positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) of at least 5 cm H₂O [1]. Importantly, Berlin eliminated the prior term “acute lung injury,” removed the pulmonary artery wedge pressure requirement (<18 mm Hg), and emphasized non-cardiogenic mechanisms of edema, thereby improving clinical applicability and prognostic stratification across mild, moderate, and severe categories [2].

Once established, ARDS frequently entails pulmonary arterial vasoconstriction and may progress to acute pulmonary hypertension, a hemodynamic complication that exacerbates right ventricular strain and can worsen gas exchange and systemic perfusion [1]. The syndrome exhibits a triphasic histopathologic evolution—from an early exudative phase through a proliferative phase and, in some cases, toward late fibrotic remodeling—with each phase corresponding to distinct ventilatory mechanics and potential responsiveness to adjunctive interventions [2]. Despite advances in critical care, ARDS continues to carry a substantial mortality burden and long-term morbidity among survivors, including neuromuscular weakness and cognitive impairment, underscoring the importance of early recognition and standardized definitions to guide therapy [1]. Treatment remains largely supportive and centers on lung-protective mechanical ventilation strategies, judicious fluid management, and timely use of adjuncts such as prone positioning in severe hypoxemia, while reserving rescue modalities for refractory cases in specialized settings [2]. Given the heterogeneity of precipitating insults and host responses, the Berlin framework provides a common language for clinical trials, benchmarking, and multidisciplinary care pathways, facilitating more precise phenotyping and the development of targeted therapies in an area where few disease-modifying options currently exist and mortality remains high [1][2].

Etiology

Acute respiratory distress syndrome (ARDS) arises from a heterogeneous set of pulmonary and extra-pulmonary insults that converge on a common pathway of diffuse alveolar injury and dysregulated inflammation [3]. In the lung, direct injuries such as infectious pneumonia or aspiration of gastric contents introduce pathogens, acid, and particulate matter that amplify epithelial damage and recruit neutrophils to

the alveolar space, where they release proteases and reactive oxygen species. Extra-thoracic triggers—including sepsis, severe trauma, massive transfusion, drowning, drug overdose, fat embolism, inhalation of toxic fumes, and acute pancreatitis—propagate a systemic inflammatory cascade with circulating cytokines and danger signals that secondarily injure the pulmonary microvasculature and alveolar epithelium, culminating in increased permeability edema and impaired gas exchange [3]. This convergence of direct and indirect pathways explains why ARDS may complicate a wide spectrum of critical illnesses and why its onset can be rapid even when the primary pathology lies outside the chest [3]. Susceptibility to ARDS is further shaped by host-related risk factors and procedural exposures. Advanced age is consistently associated with higher risk, plausibly reflecting immunosenescence, comorbidity, and reduced physiologic reserve. Female gender has been linked to differential risk in some cohorts, although the direction and magnitude of effect may vary by precipitating illness and study design. Lifestyle factors such as active smoking and heavy alcohol use are repeatedly implicated, the former through chronic airway inflammation and oxidative stress, and the latter via increased gut permeability and priming of innate immune responses that augment lung endothelial injury [3]. Major cardiovascular and aortic vascular surgeries can precipitate ARDS through ischemia-reperfusion, transfusion requirements, and systemic inflammatory response to cardiopulmonary bypass, while pulmonary contusion represents a prototypical direct parenchymal insult with local hemorrhage and inflammation that can evolve into diffuse lung injury when secondary mediators disseminate [3]. Traumatic brain injury uniquely increases ARDS risk through neurogenic pulmonary edema, catecholamine surges, and ventilatory challenges inherent to neurocritical care [2]. Pancreatitis is a classic extra-pulmonary driver, with pancreatic enzymes and cytokines fueling distal endothelial dysfunction, and certain drugs—including radiation, select chemotherapeutic agents, and amiodarone—can induce direct cytotoxic or immune-mediated lung toxicity that manifests as ARDS phenotype [3].

Risk stratification tools have been proposed to aid prevention efforts. A lung injury prevention score, which aggregates clinical exposures to estimate the likelihood of developing ARDS, appears useful for ruling out future risk in patients with low scores; however, higher scores are less discriminative and therefore less actionable for targeted prophylaxis [1]. This asymmetry underscores the current limits of predictive modeling in a syndrome defined by biological heterogeneity and variable clinical trajectories. Even so, systematic identification of modifiable exposures—minimizing high-volume transfusion when feasible, adopting lung-protective ventilation in at-risk patients, and reducing aspiration

risk through evidence-based airway practices—remains central to prevention strategies across both direct and indirect etiologic pathways [1][3].

Epidemiology

Acute respiratory distress syndrome (ARDS) represents a significant burden within critical care medicine, with considerable variability in incidence and outcome across populations and healthcare systems. In the United States, the estimated incidence ranges from 64.2 to 78.9 cases per 100,000 person-years, highlighting both the ubiquity and the ongoing public health impact of the disorder [3][4]. This incidence correlates strongly with the prevalence of underlying risk conditions such as sepsis, pneumonia, trauma, and aspiration, which serve as major precipitants of lung injury leading to ARDS. Notably, the syndrome is not restricted to tertiary care environments; it emerges frequently across diverse clinical settings where acute inflammatory or hypoxic insults occur. Among patients diagnosed with ARDS, approximately 25% initially present with mild disease, while the remaining 75% meet the criteria for moderate or severe ARDS under the Berlin definition [3][4]. However, disease progression remains a major clinical concern, as nearly one-third of mild cases advance to moderate or severe stages despite supportive therapy, reflecting the dynamic and potentially escalating nature of pulmonary inflammation and alveolar injury [4]. The prevalence of ARDS within intensive care units (ICUs) underscores its clinical prominence: approximately 10–15% of all ICU admissions fulfill diagnostic criteria, and among patients receiving mechanical ventilation, up to 23% develop ARDS at some point during their hospital course [5]. These figures reinforce the syndrome's critical relevance to respiratory management and the need for vigilance among multidisciplinary care teams.

Mortality trends in ARDS have shown gradual but measurable improvement over time. A systematic literature review revealed a mean annual reduction in mortality of approximately 1.1% between 1994 and 2006, coinciding with the widespread adoption of lung-protective ventilation strategies, improved sepsis management, and advances in supportive care [6][7]. Despite these encouraging trends, ARDS continues to carry a high mortality rate, with pooled estimates across studies averaging around 43% [6]. Importantly, the risk of death rises in proportion to disease severity: approximately 27% for mild cases, 32% for moderate disease, and 45% for severe presentations [7]. These gradations not only reflect escalating physiologic derangements but also underscore the importance of early recognition and timely implementation of evidence-based interventions to prevent progression. Globally, ARDS incidence and outcomes exhibit regional variation due to differences in healthcare infrastructure, diagnostic criteria adherence, and resource availability.

Nonetheless, the condition remains a leading cause of morbidity and mortality among critically ill patients worldwide. Continued surveillance, early risk identification, and multidisciplinary management remain pivotal to improving epidemiologic outcomes and reducing the overall healthcare burden associated with this devastating syndrome [3][5][7].

Pathophysiology

Acute respiratory distress syndrome (ARDS) represents a complex and stereotypic physiological and pathological response to a diverse array of injurious stimuli, encompassing both direct pulmonary and indirect systemic insults [8]. Despite the heterogeneity of its precipitating causes, the final common pathway involves extensive alveolar–capillary membrane disruption, inflammatory infiltration, and altered microvascular permeability. These interrelated processes culminate in severe impairment of gas exchange, progressive hypoxemia, and increased work of breathing. ARDS typically evolves through three overlapping but distinguishable phases—exudative, proliferative, and fibrotic—each defined by distinct cellular, molecular, and structural alterations within the lung parenchyma. The initial exudative phase begins within hours of the inciting event and is characterized by acute injury to both alveolar epithelial type I and capillary endothelial cells. This damage leads to the loss of tight junction integrity and increased permeability of the alveolar–capillary barrier, resulting in extravasation of protein-rich plasma into the alveolar space [8]. The ensuing alveolar edema is compounded by the inactivation and depletion of pulmonary surfactant, promoting alveolar collapse and atelectasis. Inflammatory mediators, including interleukin-1, interleukin-6, tumor necrosis factor- α , and transforming growth factor- β , amplify leukocyte recruitment and perpetuate endothelial dysfunction. The accumulation of neutrophils within the interstitium and alveolar spaces further exacerbates tissue injury through the release of proteolytic enzymes and reactive oxygen species. Microscopically, this stage is hallmarked by hyaline membrane formation lining the alveoli, widespread edema, and necrotic epithelial debris, all of which contribute to profound ventilation–perfusion mismatch and refractory hypoxemia [8][9].

As the disease progresses, many patients enter the proliferative phase, typically between days seven and twenty-one. During this phase, the inflammatory response begins to subside, and the reparative mechanisms dominate. Type II pneumocytes proliferate to repopulate denuded alveolar surfaces and restore epithelial integrity, while macrophages shift toward a reparative phenotype, clearing necrotic debris and modulating extracellular matrix deposition.

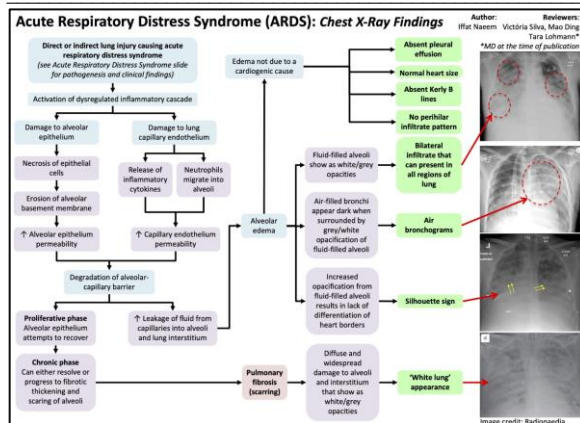


Figure-1: Acute respiratory distress syndrome pathophysiology, symptoms, and XRD images.

Fibroblasts infiltrate the interstitium, synthesizing collagen and provisional connective tissue scaffolds that help stabilize the injured alveoli. Clinically, lung compliance begins to improve, and oxygenation may show gradual recovery; however, the architectural remodeling that ensues can predispose the lung to areas of persistent stiffness and reduced elastic recoil. Vascular remodeling and intimal thickening of small pulmonary arteries may develop, setting the stage for pulmonary hypertension that contributes to right ventricular strain and systemic hypoperfusion [9]. In a subset of patients, particularly those with severe or protracted disease, ARDS advances to the fibrotic phase, signaling incomplete resolution of the acute process. Persistent fibroblast activation and unregulated collagen deposition lead to irreversible fibrosis of the interstitium and alveolar spaces. This fibrosis reduces the overall functional lung volume, leading to a so-called “baby lung” phenomenon, in which relatively small areas of normally aerated parenchyma must accommodate the entire tidal ventilation [9]. The resultant regional heterogeneity—areas of dense consolidation adjacent to relatively spared tissue—creates uneven mechanical stress distribution. This differential compliance underlies the characteristic patchy radiographic appearance and explains the varying responses to ventilatory strategies such as the application of positive end-expiratory pressure (PEEP). Although PEEP may recruit collapsed alveoli and improve oxygenation, excessive pressures risk overdistention of unaffected alveoli, causing secondary ventilator-induced injuries such as volutrauma, barotrauma, and atelectrauma [8].

Another critical feature of ARDS pathophysiology is vascular dysfunction and the development of pulmonary hypertension. Hypoxic pulmonary vasoconstriction, microthrombi formation, and endothelial swelling increase pulmonary vascular resistance, impairing right ventricular output and worsening ventilation-perfusion imbalance. The ensuing circulatory compromise aggravates tissue hypoxia and metabolic acidosis, compounding systemic inflammation and multi-organ dysfunction

[9]. Furthermore, systemic inflammatory mediators released from the injured lung may initiate or amplify distant organ injury, highlighting ARDS as a multisystem disorder rather than an isolated pulmonary phenomenon. In summary, ARDS embodies a cascade of interdependent pathological processes beginning with alveolar-capillary disruption, evolving through cellular regeneration and remodeling, and culminating—if unmitigated—in fibrosis and pulmonary hypertension. The hallmark non-uniformity of injury results in spatial heterogeneity of lung mechanics, a central challenge in mechanical ventilation management. Ultimately, these complex pathophysiological changes manifest clinically as impaired gas exchange, decreased lung compliance, and progressive pulmonary hypertension, forming the foundation upon which current diagnostic and therapeutic strategies are built [8][9].

Histopathology

The histopathologic hallmark of acute respiratory distress syndrome (ARDS) is a pattern of diffuse alveolar damage (DAD) that, while characteristic, is not pathognomonic and can be seen in multiple clinical contexts [8]. In the early, exudative phase, injury to alveolar type I pneumocytes and the pulmonary capillary endothelium disrupts the integrity of the alveolar-capillary barrier, allowing leakage of protein-rich plasma and erythrocytes into the airspaces. This process produces prominent alveolar edema and intra-alveolar fibrin deposition, often coalescing into eosinophilic hyaline membranes that line alveolar septa and ducts. Interstitial edema, capillary congestion, and varying degrees of alveolar hemorrhage accompany these changes, reflecting both increased permeability and microvascular injury [8]. Neutrophils accumulate within alveolar capillaries and the interstitium, contributing proteases and reactive oxygen species that exacerbate epithelial and endothelial damage. Surfactant dysfunction and type I cell loss promote alveolar collapse, further impairing gas exchange and setting the stage for the radiographic and physiologic abnormalities that define the clinical syndrome [8]. With progression into the organizing, or proliferative, phase, the histology shifts toward repair and remodeling. Type II pneumocytes proliferate to re-epithelialize denuded surfaces, and interstitial fibroblasts expand within edematous septa, depositing collagen and provisional extracellular matrix. Intra-alveolar organization of the fibrinous exudate may be seen as fibroblastic plugs extending into alveolar ducts, while the interstitium thickens owing to ongoing fibroplasia. Vascular alterations, including endothelial swelling, microthrombi, and intimal proliferation in small pulmonary arteries, are common correlates that contribute to rising pulmonary vascular resistance. Although hyaline membranes may recede as epithelial continuity is restored, the lingering interstitial expansion and evolving fibrosis can leave a footprint of decreased compliance, even as oxygenation stabilizes [8]. In cases that evolve to a

fibrotic phase, dense collagen deposition, architectural distortion with cystic change, and traction bronchiectasis may supervene, shrinking the volume of normally aerated parenchyma and entrenching the “baby lung” physiology recognized at the bedside [8].

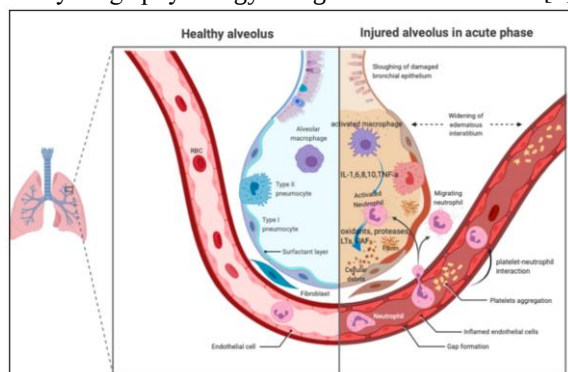


Figure-2: Acute Respiratory distress syndrome histopathology.

Importantly, none of these microscopic features is specific to ARDS; rather, they represent a stereotyped response of the lung to severe injury from diverse etiologies, including sepsis, viral or bacterial pneumonia, aspiration, toxic inhalation, and transfusion reactions [8]. Consequently, surgical lung biopsy is rarely required for diagnosis, which remains clinical and radiographic, but histopathology can be useful when the presentation is atypical or when alternative entities such as diffuse alveolar hemorrhage, acute eosinophilic pneumonia, vasculitides, or drug-induced lung disease are under consideration. Even then, sampling error is a persistent challenge given the patchy distribution of injury, with dependent regions typically more extensively involved than nondependent areas. Overall, the histologic spectrum—from exudative edema and hyaline membranes to organizing fibroplasia and, in some, end-stage fibrosis—mirrors the temporal clinical course of ARDS and underpins its cardinal manifestations of hypoxemia, decreased lung compliance, and pulmonary hypertension [8].

History and Physical

Acute respiratory distress syndrome (ARDS) is a clinical syndrome defined by the rapid onset of severe hypoxemia and respiratory distress in the setting of a known precipitating illness or injury. The presentation typically develops within 6 to 72 hours following the inciting event and progresses quickly to respiratory failure, necessitating mechanical ventilation and intensive care unit (ICU) management [8][9]. The historical evaluation and physical examination are central to establishing the diagnosis and uncovering the underlying cause, as ARDS itself represents a final common pathway of acute lung injury rather than a singular disease entity.

History

The clinical history in ARDS is directed primarily toward identifying the precipitating insult. In cases where patients can communicate, the earliest

symptom is usually progressive dyspnea, initially mild and exertional, that worsens rapidly over several hours. Within 12 to 24 hours, dyspnea intensifies and is accompanied by tachypnea, restlessness, and increasing oxygen requirements. Eventually, patients experience profound respiratory distress and fatigue that mandates ventilatory support to prevent hypoxia [8]. The history should explore potential pulmonary causes, such as pneumonia or aspiration, and extrapulmonary causes, including sepsis, trauma, pancreatitis, or massive transfusion. When the etiology is not immediately apparent, a detailed review of recent events is crucial. This includes inquiry into recent surgeries, drug exposures, transfusions, episodes of aspiration, near-drowning incidents, or inhalation of toxic fumes. A travel and occupational history may reveal exposure to environmental toxins or pathogens. Family members or caregivers may provide critical collateral information in patients who are intubated or obtunded. In the intensive care setting, ARDS frequently arises in patients already hospitalized for another critical illness—particularly sepsis or polytrauma—so reviewing hospital course and interventions (e.g., transfusions or fluid overload) is vital in uncovering the initiating factor [9].

Physical Examination

The physical examination of a patient with ARDS reflects both the underlying systemic illness and the severe derangements in gas exchange characteristic of the syndrome. Most patients present with tachypnea, labored breathing, and the use of accessory respiratory muscles. Early in the course, they may be anxious and diaphoretic, but as hypoxemia worsens, cyanosis—either central or peripheral—may become evident. Despite administration of 100% supplemental oxygen, patients often maintain low oxygen saturation levels, underscoring the refractory nature of ARDS-related hypoxemia [8]. Auscultation typically reveals diffuse inspiratory crackles (rales), often most pronounced at the lung bases, though in severe cases they may be heard throughout the chest. The intensity of breath sounds can vary depending on the degree of consolidation and alveolar collapse. Importantly, cardiac examination usually lacks findings consistent with left-sided heart failure, such as an S3 gallop or elevated jugular venous pressure, helping to distinguish ARDS from cardiogenic pulmonary edema. Percussion may reveal dullness in areas of consolidation, and tactile fremitus can be increased over infiltrated lung zones. Systemic manifestations often parallel the severity of the inciting process. Tachycardia, fever or hypothermia, and hypotension may signal sepsis or shock, while altered mental status may result from hypoxia, hypercapnia, or multi-organ dysfunction. As the disease advances, patients often exhibit signs of respiratory muscle fatigue, including shallow respirations, paradoxical abdominal motion, and decreased chest excursion. These findings herald

impending respiratory failure and the need for mechanical ventilation [9].

Clinical Correlation

The constellation of acute respiratory distress, bilateral pulmonary infiltrates, and refractory hypoxemia in the setting of a known risk factor strongly suggests ARDS. Physical examination findings, while non-specific, contribute to differentiating ARDS from other causes of respiratory failure such as congestive heart failure, pneumonia without diffuse alveolar damage, or pulmonary embolism. When integrated with historical data and imaging findings, the bedside evaluation becomes indispensable in the rapid identification and timely management of ARDS. In summary, the history and physical examination in ARDS center on the detection of an inciting event, recognition of the rapid progression of respiratory distress, and differentiation from cardiogenic causes of pulmonary edema. The syndrome's defining clinical features—dyspnea, tachypnea, refractory hypoxemia, and diffuse crackles—reflect the underlying pathophysiologic triad of alveolar-capillary injury, decreased lung compliance, and ventilation-perfusion mismatch [8][9]. Early identification through meticulous clinical assessment remains crucial, as prompt supportive management can significantly improve outcomes and mitigate the cascade of multi-organ dysfunction that often accompanies severe ARDS.

Evaluation

The evaluation of acute respiratory distress syndrome (ARDS) proceeds from a syndromic diagnosis anchored in standardized criteria to a targeted workup that clarifies etiology, excludes cardiogenic edema, and surveils for multisystem complications. The diagnostic framework requires an acute onset of respiratory failure with bilateral pulmonary opacities on chest radiography or computed tomography that cannot be fully explained by cardiac failure or fluid overload, together with impaired oxygenation quantified by a $\text{PaO}_2/\text{FiO}_2$ ratio less than 300 mm Hg under conditions of standardized ventilatory support [2]. Severity stratification further refines prognosis and guides the intensity of supportive strategies: mild disease corresponds to a $\text{PaO}_2/\text{FiO}_2 >200$ mm Hg but ≤ 300 mm Hg, moderate disease to a $\text{PaO}_2/\text{FiO}_2 >100$ mm Hg but ≤ 200 mm Hg, and severe disease to a $\text{PaO}_2/\text{FiO}_2 \leq 100$ mm Hg, with escalating mortality and fewer ventilator-free days observed as hypoxemia worsens [2]. Cross-sectional imaging can be particularly informative in complex presentations; computed tomography delineates the nonuniform, dependent-predominant pattern of consolidation typical of ARDS and assists in recognizing alternative or concurrent processes such as pneumothorax, pleural effusion, mediastinal lymphadenopathy, or barotrauma, thereby ensuring that radiographic infiltrates are correctly attributed to pulmonic rather than cardiogenic or extrapulmonary causes [2].

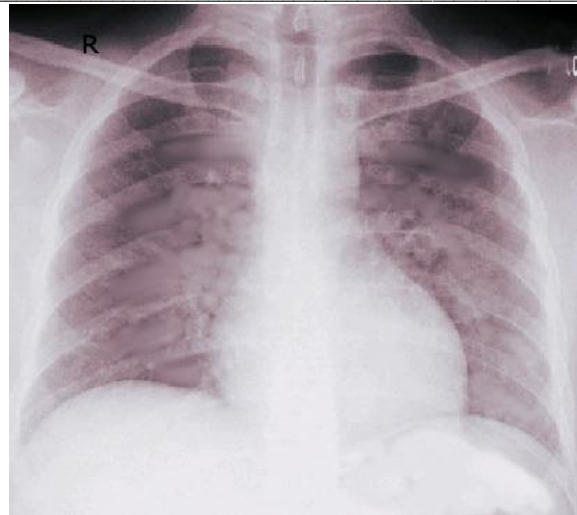


Figure-3: Acute Respiratory Distress Syndrome.

Central to evaluation is the systematic exclusion of hydrostatic (cardiogenic) edema and the assessment of any concomitant cardiac contribution to respiratory failure. In this context, noninvasive hemodynamic appraisal is preferred. Transthoracic echocardiography provides real-time insights into left ventricular systolic and diastolic function, right ventricular performance, and pulmonary pressures; when integrated with clinical and laboratory data, it offers a reliable means to differentiate ARDS from decompensated heart failure without exposing patients to catheter-related risks [2]. Additional noninvasive modalities—thoracic bioimpedance and pulse contour analysis—may augment trends in cardiac output and vascular resistance, particularly when vasopressors or high levels of positive end-expiratory pressure complicate interpretation of static indices [2]. Historically, pulmonary artery catheters were deployed to measure filling pressures and pulmonary capillary wedge pressure; however, routine use is controversial and generally discouraged given the lack of outcome benefit and the availability of robust noninvasive alternatives, reserving invasive monitoring for select hemodynamically unstable cases in which diagnostic uncertainty persists despite comprehensive noninvasive evaluation [2]. When infection is suspected—especially ventilator-associated or aspiration-related pneumonias—bronchoscopy with bronchoalveolar lavage can be invaluable for microbiologic diagnosis, antimicrobial stewardship, and exclusion of alternative pathologies such as diffuse alveolar hemorrhage; in carefully selected patients, bronchoscopic sampling refines therapy without materially worsening gas exchange when performed with meticulous ventilatory coordination [2].

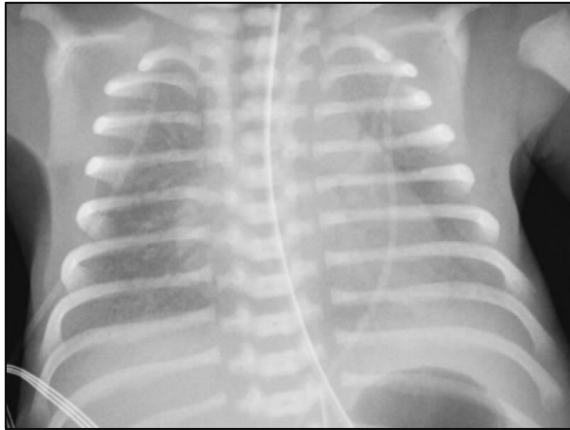


Figure-4: Chest radiograph of a preterm neonate with respiratory distress syndrome.

Beyond establishing the syndrome and clarifying cardiac contributions, evaluation must be etiologically directed, as ARDS is a final common pathway of diverse inflammatory insults. The clinical and laboratory program should therefore be guided by suspected precipitants—sepsis, pneumonia, trauma, pancreatitis, transfusion reactions, or toxic inhalational exposures—while concurrently screening for the multi-organ dysfunction that frequently accompanies severe ARDS. Because renal, hepatic, and hematopoietic derangements are common and prognostically salient, routine surveillance often includes a complete blood count with differential to monitor leukocyte trajectories and cytopenias; a comprehensive metabolic panel for renal and hepatic indices; and targeted electrolytes such as magnesium, ionized calcium, and phosphorus, which influence diaphragmatic performance and arrhythmic risk in hypoxemic, catecholamine-exposed patients [10][11][12]. Serial blood lactate measurement helps assess global perfusion and the adequacy of resuscitation in septic phenotypes, while coagulation studies can uncover disseminated intravascular coagulation or anticoagulant-related bleeding risks in the context of microvascular injury and critical illness coagulopathy [10][11][12]. Cardiac biomarkers, including troponin, conventional cardiac enzymes, and CK-MB, assist in detecting demand ischemia, concomitant myocardial injury, or stress cardiomyopathy that may complicate ventilatory management and hemodynamic stability [10][11][12]. These assays, interpreted longitudinally, inform ventilator settings, fluid strategy, and the safe deployment of adjunctive therapies such as prone positioning or neuromuscular blockade.

Arterial blood gas analysis remains essential for quantifying oxygenation and ventilatory status, contextualizing the $\text{PaO}_2/\text{FiO}_2$ ratio within the prevailing ventilator parameters, and tracking the response to lung-protective strategies. Adjunctive bedside imaging, particularly thoracic ultrasound, can complement radiography by identifying pleural effusions amenable to drainage, confirming

pneumothorax in barotrauma, and characterizing parenchymal patterns consistent with diffuse interstitial syndrome; however, ultrasound findings should be integrated with the broader clinical picture to avoid misclassification. Ultimately, the evaluation of ARDS is iterative and multidisciplinary, linking standardized diagnostic criteria to judicious cardiac assessment, targeted microbiological investigation, and comprehensive laboratory surveillance. This integrative approach ensures early recognition, accurate phenotyping, and timely escalation of evidence-based supportive care while minimizing unnecessary invasive procedures and aligning diagnostics with pathophysiologic priorities in a syndrome marked by heterogeneity and high acuity [2][10][11][12].

Treatment / Management

The contemporary management of acute respiratory distress syndrome (ARDS) is fundamentally supportive and directed toward four overarching goals: reducing shunt fraction, increasing oxygen delivery, decreasing systemic oxygen consumption, and avoiding iatrogenic lung injury. These aims frame every bedside decision—from ventilator settings and fluid stewardship to sedation depth and mobilization—and they emphasize that the syndrome's pathobiology is largely unresponsive to single “curative” interventions. Instead, outcomes improve when clinicians apply a coordinated bundle of evidence-based strategies that minimize ongoing injury while the lung heals. Patients typically require invasive mechanical ventilation, vigilant avoidance of fluid overload through judicious diuresis, and early enteral nutrition while gradual improvement is anticipated under a lung-protective paradigm [1]. The manner of ventilation is itself a critical determinant of recovery because injudicious settings amplify alveolar strain and perpetuate diffuse alveolar damage; consequently, modern care prioritizes the prevention of volutrauma (excessive tidal strain), barotrauma (excessive plateau and transalveolar pressures), and atelectrauma (cyclic opening–closing with shear) in every phase of illness [13].

Initial Stabilization and Supportive Goals

Early resuscitation stabilizes gas exchange and systemic perfusion while longer-term strategies are implemented. Oxygenation targets are individualized, but conventional practice accepts peripheral oxyhemoglobin saturations in the high 80s to mid-90s range to avoid excessive inspired oxygen fractions that risk absorptive atelectasis and oxygen toxicity [1]. Concomitantly, clinicians reduce oxygen consumption by treating fever, agitation, and shivering; optimizing analgesia and light sedation; and correcting acid–base disturbances that drive tachypnea and adrenergic tone. Hemodynamic support emphasizes maintenance of adequate mean arterial pressure and cardiac output, using balanced crystalloids for initial resuscitation in shock and early,

judicious vasopressors to avert positive fluid balance once perfusion targets are met. Thereafter, a conservative fluid strategy with diuretics is favored to lower extravascular lung water and improve lung mechanics, provided that end-organ perfusion is preserved [15][16]. Because ARDS frequently coexists with sepsis or pneumonia, prompt, appropriately dosed antimicrobials are essential while microbiologic diagnostics proceed; source control is pursued as indicated to reduce ongoing inflammatory drive [15].

Lung-Protective Mechanical Ventilation

Lung-protective ventilation is the cornerstone of ARDS management and centers on the NIH-NHLBI ARDS Clinical Network protocol (ARDSnet) targets: tidal volumes of 4–8 mL/kg of ideal body weight, respiratory rates as high as 35 breaths per minute to maintain adequate minute ventilation, plateau pressure (Pp) maintained below 30 cm H₂O, permissive hypercapnia with a pH goal of 7.30 to 7.45, and an inspiratory-to-expiratory time ratio less than 1 when feasible [1]. Oxygenation goals typically involve SpO₂ between 88% and 95% while using the lowest FiO₂ that achieves these targets; the protocol recognizes the central role of positive end-expiratory pressure (PEEP) in preventing derecruitment and allows low-PEEP/FiO₂ or high-PEEP/FiO₂ tables, with PEEP up to 24 cm H₂O in patients needing 100% FiO₂ [1]. In select scenarios—particularly when oxygenation remains refractory despite carefully titrated PEEP—sacrificing the conventional inspiratory-to-expiratory ratio to adopt inverse ratio ventilation may be appropriate to lengthen mean airway pressure and augment alveolar recruitment, albeit with heightened vigilance for hemodynamic compromise. Clinicians continually balance under-recruitment against overdistention in a lung characterized by regional heterogeneity. The “baby lung” concept underscores that a relatively small fraction of normally aerated tissue receives the full ventilatory load; thus, even modest tidal volumes can impose substantial strain. Adherence to low tidal volumes and plateau pressure limitation remains the single most consistently supported intervention to reduce ventilator-induced lung injury, shorten duration of ventilation, and improve survival in ARDS cohorts [1][13]. Daily assessment of driving pressure—the difference between plateau pressure and PEEP—can provide an adjunctive risk signal; while not a formal protocol target, lower driving pressures often accompany lung-protective settings and better compliance, and they guide nuanced adjustments in PEEP and tidal volume to minimize global strain [13].

Strategies to Mitigate Barotrauma and Optimize Mechanics

Barotrauma risk rises when plateau pressures exceed safe thresholds, when dynamic hyperinflation ensues from insufficient expiratory time, or when heterogeneous lung units experience uneven distribution of pressure and flow. Several pragmatic

ventilator adjustments help maintain Pp below 30 cm H₂O: reducing tidal volume toward 4 mL/kg IBW where tolerated; avoiding excessive PEEP in the absence of recruitability; increasing inspiratory rise time to smooth pressure delivery; and moderating inspiratory flow rates to decrease peak and plateau pressures without sacrificing adequate alveolar ventilation [13]. Because lung compliance and airway resistance evolve over hours to days, frequent reassessment is essential; improvements in compliance justify weaning PEEP and FiO₂, whereas sudden deteriorations should trigger a search for air leaks, mucus plugging, positional changes, or hemodynamic alterations. Improving compliance also depends on identifying and treating extra-pulmonary causes that stiffen the respiratory system. Pneumothorax, hemothorax, and large pleural effusions require drainage; thoracic compartment syndrome and massive chest wall edema call for hemodynamic optimization and, occasionally, surgical consultation; intraabdominal hypertension elevates diaphragmatic load and may compel abdominal decompression in extreme cases. When dyssynchrony with the ventilator worsens mechanics or drives injurious tidal swings, targeted adjustments in trigger sensitivity and flow profiles, careful analgesia, and light sedation are favored before deeper sedation is considered [13]. Neuromuscular blockade can be an effective short-term adjunct during the most severe early phase: initial studies suggested that a 48-hour infusion within the first 48 hours of ARDS improved 90-day survival and increased ventilator-free days, presumably by eliminating patient-ventilator dyssynchrony and reducing oxygen consumption and inflammatory load [13]. Subsequent evidence, however, has tempered enthusiasm; a large trial published in 2019 found no significant mortality benefit with continuous paralysis compared to lighter sedation strategies, reinforcing that paralysis should be reserved for refractory hypoxemia, profound dyssynchrony, or facilitation of prone positioning rather than used routinely [14].

Adjunctive and Alternative Ventilatory Modes

Several alternative modes are used selectively to improve oxygenation or synchrony. Airway pressure release ventilation (APRV) increases mean airway pressure via a long high-pressure phase with brief releases, potentially recruiting dependent regions while permitting spontaneous breathing; although APRV can transiently enhance oxygenation, robust mortality benefits have not been demonstrated, and careful titration is needed to avoid overdistention [13]. Recruitment maneuvers aim to open collapsed alveoli using transient high pressures; they may achieve short-lived improvements in oxygenation but similarly lack consistent outcome gains and carry risks of hypotension and barotrauma [13]. In pediatrics, high-frequency oscillatory ventilation has specific niche applications, whereas in adults it has not shown survival benefit and is generally not used as routine

rescue therapy. Noninvasive respiratory support can be appropriate in mild—and occasionally moderate—ARDS when meticulous monitoring and rapid intubation capability are assured. Continuous positive airway pressure, bilevel positive airway pressure, and proportional-assist ventilation can avert intubation in carefully selected patients with preserved mental status and secretion management, while high-flow nasal cannula offers improved comfort, reduced dead space, and modest PEEP-like effects [13]. Failure criteria must be explicit—worsening oxygenation, persistent tachypnea, increased work of breathing, or mental status changes mandate early escalation to invasive ventilation to avoid emergent, high-risk intubations.

Prone Positioning

Prone positioning is among the most impactful adjuncts for severe hypoxemia in ARDS. By redistributing transpulmonary pressures, improving dorsal lung recruitment, homogenizing regional strain, and enhancing secretion drainage, proning rapidly improves oxygenation in a majority of patients—often between 50% and 70%—and allows meaningful reductions in FiO₂ and PEEP requirements [15][16]. To maximize benefit, protocols maintain the prone posture for prolonged daily sessions, typically at least eight hours, with meticulous attention to pressure point protection, ocular care, and securement of tubes and lines to mitigate the principal adverse event: accidental dislodgement. Teams trained in standardized turning procedures can implement proning safely even in hemodynamically tenuous patients; potential contraindications such as unstable spinal fractures, open abdomen, or raised intracranial pressure require individualized risk–benefit assessment. Although the physiologic response is often immediate, the clinical benefits emerge over days as recruitable units remain open and oxygen toxicity risk falls [15][16].

Nonventilatory Strategies and Conservative Fluid Management

Beyond ventilation, nonventilatory measures materially shape outcomes. After initial shock resuscitation, a conservative fluid strategy reduces ventilator days and improves lung function by lowering hydrostatic contributions to edema without sacrificing renal outcomes when carefully monitored [15][16]. Continuous monitoring of urine output, lactate clearance, and dynamic hemodynamic indices guides diuretic dosing and vasopressor support to maintain perfusion while avoiding positive fluid balances. Spontaneous breathing trials and sedation minimization are coordinated with fluid off-loading to accelerate liberation from the ventilator as gas exchange permits. Extracorporeal membrane oxygenation (ECMO) serves as salvage therapy for refractory hypoxemia or hypercapnia despite optimized lung-protective ventilation, high PEEP, proning, and neuromuscular blockade. Venovenous

ECMO offloads gas exchange demands and enables ultra-protective ventilator settings that might otherwise be unsustainable; however, two major trials that compared venovenous ECMO to optimized conventional care did not demonstrate a mortality difference overall, emphasizing that careful patient selection, center experience, and stringent protocols are crucial to realize potential benefits [17][18]. Where available, early consultation with an ECMO-capable center is reasonable when standard adjuncts fail, particularly in younger patients without prohibitive comorbidities and with potentially reversible etiologies [17][18].

Pharmacologic Therapies, Sedation, and Analgesia

Pharmacologic approaches in ARDS remain largely supportive and etiology-specific. Routine use of systemic glucocorticoids is not universally recommended; instead, steroids are considered in patients whose ARDS arises from steroid-responsive processes such as acute eosinophilic pneumonia, and in select patients with refractory sepsis or severe community-acquired pneumonia where immunomodulation may confer benefit [19]. For patients who remain in moderate to severe ARDS early in the disease course—within about 14 days of onset, with PaO₂/FiO₂ ratios below 200 mm Hg despite low tidal volume ventilation—some protocols allow for glucocorticoids as an adjunctive measure, though dosing, tapering, and timing require strict attention to avoid complications [19]. Conversely, in less severe ARDS, or when the syndrome persists beyond two weeks without improvement, glucocorticoids are generally avoided because risk–benefit tilts unfavorably. Importantly, corticosteroid use is associated with worse outcomes in certain viral pneumonias, particularly influenza, and must therefore be considered carefully in pathogen-specific contexts [20]. Sedation and analgesia strategies aim to achieve ventilator synchrony, reduce oxygen consumption, and support prone positioning while minimizing delirium and neuromuscular weakness. Analgosedation—prioritizing opioid analgesia before sedative hypnotics—can reduce agitation and dyssynchrony, and daily sedation interruption with readiness testing facilitates earlier extubation once oxygenation stabilizes. When neuromuscular blockade is used for short durations, concurrent deep sedation is mandatory, and rigorous eye and skin care protocols mitigate immobilization complications [13][14]. Prophylaxis against venous thromboembolism is universally advised because critical illness, immobility, and systemic inflammation converge to raise thrombosis risk; pharmacologic prophylaxis is preferred unless contraindicated, with mechanical methods as adjuncts [16]. Similarly, stress ulcer prophylaxis is indicated in high-risk patients to prevent gastrointestinal bleeding, balancing benefits against potential infection risks in ventilated populations [16].

Nutritional and Metabolic Management

Early enteral nutrition supports gut integrity, attenuates systemic inflammation, and provides substrate for healing in ARDS. While specialized formulations have been studied, the most consistent recommendations endorse timely initiation of enteral feeds tailored to caloric and protein requirements, with careful glycemic management as part of an ICU metabolic bundle [16]. Some studies have suggested that high-fat, low-carbohydrate diets enriched with gamma-linolenic acid and eicosapentaenoic acid can improve oxygenation indices, though findings are heterogeneous and not uniformly translated into outcome benefits; such formulations may be reasonable in selected patients under dietetic supervision [16]. Glycemic control targets a moderately permissive range—commonly 140 to 180 mg/dL—rather than intensive insulin regimens that seek 80 to 110 mg/dL, given the higher risk of hypoglycemia and associated morbidity in tightly controlled protocols across critically ill cohorts [16]. Micronutrient repletion, particularly phosphate and magnesium, is prioritized to support diaphragmatic function and avoid arrhythmias during high respiratory workloads and beta-agonist exposure.

Prevention of Device- and ICU-Related Complications

Because prolonged mechanical ventilation and immobility predispose to a spectrum of complications, comprehensive ICU bundles are integral to ARDS care. Elevating the head of the bed, meticulous oral care, subglottic suctioning where available, and daily readiness assessments reduce ventilator-associated pneumonia and expedite extubation. Central venous catheters are often necessary for vasoactive infusions, frequent blood sampling, and hemodynamic monitoring; their placement demands strict sterile technique, and daily review of indication supports timely removal [16]. Pressure injury prevention hinges on frequent repositioning—especially crucial during extended prone sessions—use of pressure-relieving surfaces, and routine skin inspections documented by nursing teams. Early physical and occupational therapy, initiated as soon as hemodynamics and oxygenation allow, combats ICU-acquired weakness and hastens functional recovery; even passive range-of-motion exercises during deep sedation have benefits that accumulate over time [16]. Routine administration of mucolytics has not demonstrated consistent benefit and is not advised as a standard therapy in ARDS, though airway hygiene with adequate humidification and suctioning remains essential [21].

Escalation, Rescue Therapies, and Referral Pathways

When hypoxemia persists despite optimized lung-protective ventilation, high PEEP titration, prone positioning, and short-course neuromuscular blockade, clinicians should consider rescue therapies and early transfer to centers with advanced

capabilities. Referral pathways to ECMO-ready units are established in many regions to streamline evaluation for venovenous ECMO candidacy in patients with potentially reversible respiratory failure who fail conventional measures [17][18]. Simultaneously, the care team re-examines reversible contributors: malpositioned endotracheal tubes, mucus plugging or atelectasis amenable to bronchoscopy, occult pneumothorax, evolving pulmonary embolism, or cardiac dysfunction that has supervened on the respiratory process. Adjustment of ventilator strategy to ultra-protective settings—further reducing tidal volumes with acceptance of higher PaCO₂ (permissive hypercapnia) and carefully monitored pH—may buy time for resolution while extracorporeal options are considered [13][17].

Liberation from Mechanical Ventilation and Recovery

As the exudative phase yields to proliferative repair, gas exchange improves and ventilatory support can be gradually de-escalated. Weaning strategies emphasize daily spontaneous breathing trials, progressive reduction in PEEP and FiO₂ as oxygenation stabilizes, and continued avoidance of high tidal volumes even as compliance rebounds. Conservative fluids and diuresis aid liberation by reducing extravascular lung water, while early mobilization restores diaphragmatic function and overall endurance. Post-extubation support with high-flow nasal cannula can bridge residual hypoxemia and reduce reintubation risk in selected patients. Discharge planning recognizes the frequency of persistent functional impairments after ARDS; structured rehabilitation, close outpatient follow-up, and screening for post-intensive care syndrome—including cognitive, psychological, and neuromuscular sequelae—are integral to holistic recovery pathways [16].

Special Therapeutic Considerations and Controversies

Several corners of ARDS management remain actively debated. The role of recruitment maneuvers, for instance, varies with lung recruitability; while a patient with heavy, dependent consolidations and demonstrable oxygenation response may benefit transiently, routine application irrespective of phenotype can precipitate hypotension or barotrauma without durable gains [13]. APRV provides theoretical advantages in select patients with recruitable lungs and spontaneous breathing capacity, but as with other alternative modes, institutional familiarity and vigilant monitoring are prerequisites to safe implementation [13]. The place of neuromuscular blockade has narrowed following the 2019 trial showing no mortality difference with continuous paralysis compared to light sedation; many centers now reserve paralysis for short, clearly defined indications such as refractory hypoxemia during proning or life-threatening dyssynchrony, always anchoring the decision in careful risk-benefit

assessment [14]. Glucocorticoids, too, require nuanced application: while they may shorten time on the ventilator or improve oxygenation in certain early, persistent moderate-to-severe cases, they are generally avoided later in the course and in the context of specific viral infections like influenza, where harm signals have emerged [19][20]. Nutritional supplementation with specific lipid formulations remains an adjunct at best; attention to timing, caloric goals, and protein delivery is more consequential than any single micronutrient in most patients [16]. Finally, the absence of a clear survival advantage in randomized comparisons of venovenous ECMO to optimized standard care underscores that ECMO is a complex platform therapy whose benefits depend on timing, selection, and the expertise of multidisciplinary teams rather than a technology that guarantees improved survival in unselected populations [17][18].

The unifying theme of ARDS management is disciplined adherence to strategies that prevent further injury while physiologic healing proceeds. At the ventilator, this means low tidal volumes, plateau pressure limitation, judicious PEEP, and readiness to use adjuncts—short-course neuromuscular blockade, prone positioning, or alternative modes—when indicated, always with a view toward minimizing strain and heterogeneity [1][13][14][15][16]. Systemically, it means conservative fluids after resuscitation, targeted antimicrobials, thoughtful sedation, prevention of thromboembolic and gastrointestinal complications, and vigorous attention to skin integrity and mobilization [15][16][21]. For the minority with refractory gas exchange failure despite best conventional care, ECMO remains a rescue option in appropriate centers, evaluated early enough to be actionable yet framed by realistic expectations based on current evidence [17][18]. Glucocorticoids occupy specific niches aligned with etiology and timing, not a blanket solution, and their risks in certain viral contexts remain a firm caution [19][20]. In sum, ARDS therapy is a dynamic, multidisciplinary enterprise that transforms pathophysiologic insight into practical safeguards against further harm. The four central goals—reducing shunt, enhancing oxygen delivery, decreasing oxygen consumption, and avoiding additional injury—are achieved not by a single drug or device but by coherent, protocolized care at the bedside. When these principles are systematically applied and individualized to the patient's trajectory, they translate into more ventilator-free days, fewer complications, and improved survival in a syndrome long defined by its severity and complexity [1][13][15][16][17][18][19][20][21].

Differential Diagnosis

The differential diagnosis of acute respiratory distress syndrome (ARDS) is broad, reflecting the diverse conditions that can produce bilateral pulmonary infiltrates and acute hypoxemia.

Distinguishing ARDS from these mimicking entities is critical because management and prognosis differ substantially. The process hinges on integrating clinical history, hemodynamic data, laboratory testing, and imaging patterns with an understanding of each condition's underlying pathophysiology. Cardiogenic pulmonary edema remains the most frequent diagnostic alternative. Both ARDS and cardiogenic edema present with dyspnea, hypoxemia, and diffuse alveolar infiltrates, but cardiogenic edema arises from elevated hydrostatic pressure secondary to left ventricular dysfunction or valvular disease. Echocardiography and natriuretic peptide levels aid differentiation, with ARDS typically showing normal cardiac function and low filling pressures. The absence of cardiomegaly and Kerley B lines on imaging further supports a non-cardiogenic process. Exacerbation of interstitial lung disease (ILD) can mimic ARDS with diffuse opacities and respiratory failure. However, ILD exacerbations usually occur in patients with a chronic fibrotic background, and high-resolution CT often reveals reticular fibrosis with traction bronchiectasis. Acute interstitial pneumonia (AIP), or Hamman–Rich syndrome, represents an idiopathic form of diffuse alveolar damage indistinguishable histologically from ARDS but is diagnosed when no precipitating cause is found.

Diffuse alveolar hemorrhage (DAH) presents with similar radiographic findings but is distinguished by hemoptysis, anemia, and bronchoscopy revealing hemorrhagic return on sequential lavage. Acute eosinophilic pneumonia (AEP) likewise mimics ARDS radiographically but demonstrates marked eosinophilia in bronchoalveolar lavage fluid and dramatic steroid responsiveness. Organizing pneumonia (OP)—whether cryptogenic or secondary—often manifests with patchy consolidations that migrate over time rather than diffuse homogeneous infiltrates, and patients typically have a subacute presentation rather than abrupt deterioration. Bilateral bacterial or viral pneumonia is another key consideration, especially when sepsis coexists; microbiologic confirmation and lobar asymmetry usually clarify the diagnosis. Pulmonary vasculitis, as seen in granulomatosis with polyangiitis or microscopic polyangiitis, can present acutely with hemoptysis and alveolar infiltrates but is distinguished by systemic vasculitic manifestations and serologic markers such as ANCA positivity. Finally, disseminated malignancy—notably lymphangitic carcinomatosis—can produce diffuse infiltrates and hypoxemia; however, progression is typically more insidious, and imaging often reveals interlobular septal thickening or nodularity rather than the ground-glass opacities of ARDS. In summary, ARDS must be differentiated from cardiogenic, infectious, inflammatory, hemorrhagic, and neoplastic causes of diffuse pulmonary infiltrates. A methodical approach incorporating hemodynamic evaluation, imaging

patterns, laboratory data, and, when necessary, bronchoscopy or biopsy ensures diagnostic precision and appropriate management, preventing the misapplication of ARDS-directed therapies in non-ARDS conditions.

Prognosis

The prognosis of acute respiratory distress syndrome (ARDS) has evolved remarkably over the past several decades, transforming from a condition once associated with almost universally fatal outcomes to one with steadily improving survival rates due to advancements in critical care. Historically, the mortality of ARDS ranged between 30% and 40%, with even higher rates in the most severe cases, particularly before the implementation of evidence-based ventilatory protocols and standardized critical care practices [22]. During the 1980s and early 1990s, ARDS was widely viewed as a catastrophic endpoint of critical illness, frequently culminating in death from sepsis, multi-organ failure, or refractory hypoxemia. However, improvements in the understanding of lung-protective ventilation, earlier initiation of antibiotics, and optimization of supportive measures have collectively reduced mortality rates significantly over the past two decades [23]. Currently, overall mortality in ARDS ranges between 9% and 20%, depending on disease severity, patient age, and the presence of comorbidities. Mild ARDS typically carries a better prognosis, while mortality rates rise sharply with increasing severity and with advancing age. Elderly patients, in particular, experience higher rates of death and long-term disability due to reduced physiologic reserve, higher prevalence of chronic comorbidities, and diminished ability to recover from prolonged mechanical ventilation. Nonetheless, these improvements in survival highlight the impact of adopting low tidal volume ventilation strategies, strict control of plateau pressures, conservative fluid management, and early recognition of sepsis, which together have reshaped the natural history of the disease [22][23].

Despite these gains, ARDS continues to impose significant morbidity among survivors. The majority of patients who recover from the acute phase experience prolonged hospitalization, often requiring weeks of mechanical ventilation, sedation, and immobility. As a result, survivors frequently present with marked weight loss, poor muscle strength, and profound deconditioning at discharge. Many endure ongoing functional impairment, particularly in activities requiring physical endurance or fine motor coordination. These sequelae are often compounded by post-intensive care syndrome (PICS), a constellation of cognitive, psychological, and physical deficits that emerge following prolonged critical illness and ICU stay. The hypoxia associated with the acute illness has also been linked to persistent cognitive dysfunction, memory impairment, and difficulties with attention that can last for months after discharge, complicating reintegration into normal

social and occupational roles [22]. Pulmonary recovery following ARDS, however, is often more favorable than initially presumed. Longitudinal studies demonstrate that, for most survivors, pulmonary function tests show an almost complete return to baseline within six to twelve months, with normalization of lung volumes and diffusion capacity. This recovery reflects the lung's remarkable regenerative potential once inflammation resolves and fibroproliferation abates. Nevertheless, many patients continue to report subjective dyspnea on exertion and reduced exercise tolerance despite normal objective measures of lung function. This paradox likely reflects a combination of persistent skeletal muscle weakness, cardiac deconditioning, and subtle alterations in pulmonary microarchitecture that do not manifest in standard spirometric indices [23].

The trajectory of recovery also depends heavily on the underlying cause of ARDS. Patients with trauma- or transfusion-related ARDS tend to have better outcomes than those with sepsis-related ARDS, in which systemic inflammation and multi-organ dysfunction are more pronounced. Similarly, patients who develop ARDS secondary to direct pulmonary insults (such as pneumonia or aspiration) may experience longer ventilator dependence and slower functional recovery compared to those with indirect systemic causes. The timing of interventions, particularly the early application of lung-protective strategies and appropriate antibiotic therapy, correlates strongly with long-term outcomes and survival [22]. Long-term follow-up studies reveal that ARDS survivors are at increased risk for chronic health problems extending beyond the pulmonary system. Many develop persistent neuromuscular weakness, anxiety, depression, or post-traumatic stress disorder as part of the broader spectrum of critical illness recovery syndromes. These psychological and cognitive impairments often contribute more to long-term disability and reduced quality of life than residual pulmonary dysfunction. Accordingly, multidisciplinary rehabilitation—including physical therapy, occupational therapy, and psychological counseling—forms an essential part of post-discharge care. Patients may require months of structured rehabilitation to regain baseline independence, and even then, a substantial proportion never fully return to their pre-illness level of function [23].

Age, comorbidities, and severity of the initial insult remain the most reliable predictors of outcome. Advanced age, chronic alcohol use, preexisting pulmonary disease, and higher illness severity scores on admission all portend poorer prognosis. Additionally, prolonged mechanical ventilation, high oxygen requirements, and unresolving multi-organ failure predict higher mortality and long-term morbidity. Conversely, early identification, timely implementation of evidence-based ventilation strategies, and prevention of secondary infections contribute to improved outcomes. The use of

adjunctive therapies such as prone positioning, conservative fluid management, and structured sedation protocols has further enhanced survival by minimizing ventilator-associated complications and reducing systemic stress [22][23]. In conclusion, while the prognosis of ARDS has improved markedly in the modern era, it remains a condition associated with considerable mortality and long-term morbidity. Contemporary mortality rates of approximately 10–20% reflect decades of progress in mechanical ventilation, sepsis management, and critical care delivery. Yet, survivors frequently face months of rehabilitation and a new baseline defined by physical deconditioning, cognitive deficits, and psychosocial stress. Although most patients ultimately regain near-normal pulmonary function, many continue to struggle with exertional dyspnea and fatigue, underscoring the importance of comprehensive, multidisciplinary follow-up. Continued research into personalized ventilation strategies, anti-inflammatory therapies, and post-ICU rehabilitation holds promise for further improving survival and long-term quality of life for patients recovering from this formidable syndrome [22][23].

Complications

Acute respiratory distress syndrome (ARDS) is associated with a wide spectrum of complications arising from both the underlying disease process and the intensive interventions required for its management. Barotrauma, including pneumothorax, pneumomediastinum, or subcutaneous emphysema, remains a major complication linked to the use of high levels of positive end-expiratory pressure (PEEP) and excessive plateau pressures during mechanical ventilation. Prolonged mechanical ventilation often becomes necessary due to the severity of respiratory failure, predisposing patients to ventilator-associated pneumonia and necessitating tracheostomy for long-term airway support. Post-extubation complications such as laryngeal edema and subglottic stenosis can further prolong recovery and complicate weaning. Infection-related complications are particularly common in ARDS due to invasive lines and devices. Nosocomial infections, including catheter-related bloodstream infections, urinary tract infections, and antibiotic-resistant pneumonias, contribute significantly to morbidity and mortality. Systemic inflammation and sepsis may also precipitate renal failure, necessitating renal replacement therapy in severe cases. Additionally, prolonged immobilization and systemic inflammation predispose patients to deep venous thrombosis and pulmonary embolism, reinforcing the importance of routine prophylaxis. Beyond the acute phase, survivors frequently experience critical illness polyneuropathy and myopathy, leading to profound muscle weakness and delayed rehabilitation. Neuropsychiatric complications, including post-traumatic stress disorder (PTSD), anxiety, and depression, are also

well-documented, reflecting the psychological toll of prolonged intensive care and mechanical ventilation. Collectively, these complications underscore the need for a multidisciplinary approach emphasizing prevention, vigilant monitoring, and early rehabilitation to mitigate the long-term impact of ARDS and its treatment.

Postoperative and Rehabilitation Care

The postoperative and rehabilitative phase of acute respiratory distress syndrome (ARDS) requires a structured, multidisciplinary plan that transitions patients from life-sustaining therapies toward recovery of airway autonomy, nutrition, mobility, and psychosocial function. During this interval, many patients continue to experience gas-exchange fragility, respiratory muscle weakness, and neurocognitive symptoms attributable to critical illness and prolonged ventilation. Care teams therefore prioritize stable liberation from the ventilator, restoration of safe swallowing and nutrition, prevention of complications such as pressure injuries and venous thromboembolism, and progressive functional reconditioning. Because residual hypoxemia and deconditioning remain common, frequent clinical reassessment and goal-directed therapy are essential to prevent readmission and to consolidate the gains achieved during intensive care [24]. Rehabilitation must also anticipate the longitudinal trajectory after discharge, including home oxygen needs, caregiver training, and linkage to outpatient pulmonary and rehabilitation services, all of which reduce the burden of post-intensive care syndrome.

Tracheostomy and Percutaneous Endoscopic Gastrostomy

A substantial proportion of ARDS survivors require tracheostomy and percutaneous endoscopic gastrostomy (PEG) during recovery. Tracheostomy, typically performed around the second to third week of invasive ventilation, facilitates ventilator weaning by lowering airway resistance, improving patient comfort, enabling more effective secretion management, and allowing earlier participation in physical therapy and communication exercises. The decision to proceed is individualized and integrates oxygenation stability, expected duration of ventilation, airway protection, and goals of care. Following tracheostomy, structured weaning protocols with stepwise reductions in pressure support, daily cuff deflation trials, and progressive speaking-valve use help restore cough effectiveness and phonation while protecting against aspiration. PEG placement supports reliable enteral nutrition in patients with impaired swallow, ensuring adequate protein and caloric intake during the high catabolic state of recovery. Timing of PEG is coordinated with tracheostomy when feasible to minimize sedation and procedural exposures, and both procedures require meticulous site care, standardized decannulation criteria, and caregiver education to avoid infection or dislodgement. As

respiratory mechanics improve, tracheostomy capping and decannulation are planned in tandem with swallow rehabilitation and nocturnal oximetry to verify airway safety and ventilatory reserve, acknowledging that some patients will require a longer runway to regain full autonomy because of persistent weakness or neurocognitive sequelae of hypoxia and critical illness [24].

Nutritional Support

Malnutrition and muscle wasting are pervasive in ARDS convalescence, driven by systemic inflammation, immobility, and the metabolic demands of healing. Early and sustained enteral feeding is preferred whenever gastrointestinal function permits, as it maintains mucosal integrity and attenuates infectious risk, while parenteral nutrition is reserved for those with nonfunctional gut or persistent intolerance to enteral strategies. Dietetic assessment tailors protein targets—often 1.2 to 2.0 g/kg/day—to rebuild lean mass, and energy goals are calibrated using predictive equations or indirect calorimetry where available. Some experts advocate lower-carbohydrate, higher-fat formulations to modulate carbon dioxide production and leverage potential anti-inflammatory lipid profiles; however, no single supplement has demonstrated unequivocal superiority across ARDS populations, and thus individualized, evidence-informed plans remain paramount. Micronutrient repletion, particularly of phosphate, magnesium, and thiamine, supports respiratory muscle function and mitigates refeeding risks. As oral intake resumes, coordinated swallow evaluation addresses aspiration risk, transitioning from tube feeds to texture-modified diets and, ultimately, regular consistency as laryngeal function returns. Throughout this arc, glycemic management typically targets a moderate range to reduce catabolic stress without courting hypoglycemia, while daily weights, nitrogen balance surrogates, and functional metrics (e.g., handgrip strength) track nutritional response. The overarching aim is restoration of anabolic balance to enable participation in rehabilitation therapy and to shorten the time to independent living, recognizing that nutrition is foundational to ventilator weaning, wound healing, and overall resilience in the months following critical illness [24].

Activity

Rehabilitation begins in the ICU and intensifies postoperatively with a structured progression from in-bed mobility to upright activities and ambulation. Because ARDS survivors are at high risk for deconditioning, contractures, pressure injuries, and thromboembolism, frequent position changes, elevation of the head of the bed, and early engagement in range-of-motion exercises are core elements of care. As oxygenation stabilizes, sedation is minimized to permit active participation in therapy, with early transfer to a chair and breathing exercises to recondition the diaphragm and accessory muscles. Physical and occupational therapists develop graded

activity plans that integrate intervals of exertion and rest, balancing cardiopulmonary demand with oxygen targets and hemodynamic tolerance. Daily goals often include incremental increases in standing time, gait distance, and self-care tasks such as grooming and feeding, thereby coupling functional milestones with psychosocial recovery. For tracheostomized patients, coordinated ventilator adjustments and speaking-valve sessions enable voice reintroduction and airway clearance training. Diligent prophylaxis against venous thromboembolism continues alongside mobilization, while pressure offloading strategies and skin checks address persistent risks of device-related injury during prolonged prone or supine intervals. The ultimate objective is to build endurance and strength sufficient for safe discharge to home or rehabilitation facilities, supported by caregiver education on energy conservation, oxygen equipment, and tracheostomy care when applicable. This activity-centered approach shortens convalescence, reduces readmissions, and mitigates the long-term functional limitations that shadow many ARDS survivors [24].

Consultations

Optimal postoperative and rehabilitation care for ARDS hinges on timely consultation with an interprofessional cadre whose complementary expertise accelerates recovery and mitigates complications. Pulmonologists and intensivists guide ventilator weaning strategies, evaluate residual parenchymal disease, and calibrate oxygen therapy while surveilling for late complications such as tracheal stenosis or bronchiectasis. Respiratory therapists titrate settings, coach airway clearance techniques, and facilitate transitions from invasive support to high-flow nasal cannula or room air, coordinating with speech-language pathologists for swallow and voice rehabilitation in tracheostomized patients. Infectious disease specialists refine antimicrobial stewardship in the wake of ventilator-associated infections, line sepsis, or persistent pneumonias, ensuring treatment courses align with culture data and minimizing antibiotic resistance. Dietitians and nutritionists craft individualized feeding regimens that reconcile caloric and protein targets with glycemic safety and gastrointestinal tolerance, adapting plans as oral intake resumes. Physical and occupational therapists orchestrate graduated mobilization and activities of daily living, setting measurable goals that link respiratory gains to practical independence and safe discharge planning. Pharmacists reconcile complex medication regimens, optimize analgesia and sedation, and monitor for interactions among anticoagulants, antibiotics, and diuretics. Nurses provide the continuous assessment backbone, detect early deterioration, deliver skin and line care, educate families, and integrate multiple consultant recommendations into coherent bedside execution. Social workers, case managers, and, when appropriate, chaplains address home services, equipment procurement, financial constraints, and

psychosocial resilience during extended recovery. This collaborative scaffolding is particularly vital for patients with cognitive or functional impairment from hypoxia or prolonged immobilization, in whom sustained, coordinated support determines the pace and completeness of recovery. The cumulative effect of early, well-structured consultation is fewer complications, smoother transitions of care, and improved readiness for discharge to appropriate rehabilitation settings where gains can be consolidated [24].

Patient Education

While ARDS cannot be proactively prevented in a strict sense, its incidence and severity can be attenuated through risk mitigation and patient-centered education across the continuum of care. In hospital environments, adherence to aspiration precautions—most notably head-of-bed elevation during and after enteral feeding—reduces the likelihood of aspiration pneumonitis in vulnerable patients. Early identification of sepsis and prompt, guideline-concordant therapy curb the inflammatory cascades that culminate in diffuse alveolar damage, and meticulous perioperative strategies limit transfusion exposures and fluid overload in high-risk surgeries. Equally important is the consistent application of lung-protective ventilation in at-risk patients who are mechanically ventilated for other reasons, including those with trauma, major surgery, or severe pneumonia, to avert ventilator-induced lung injury and progression to full ARDS. Education directed at patients and families focuses on recognizing early respiratory deterioration, the rationale behind conservative fluid strategies, and the importance of participating in mobilization and respiratory exercises as soon as clinically feasible. For those transitioning from ICU to ward and then to home or rehabilitation facilities, structured teaching on tracheostomy care, PEG maintenance, nutrition goals, and safe oxygen use reduces readmissions and device-related complications. Smoking cessation counseling, vaccination against influenza and pneumococcus, and management of chronic conditions such as diabetes and heart failure further decrease susceptibility to severe infections and cardiopulmonary decompensation that can precipitate ARDS. At the system level, standardized care pathways that embed aspiration precautions, sedation minimization, delirium prevention, and early mobility reinforce consistent risk reduction across teams and shifts. Ultimately, deterrence is not a single intervention but a package of preventive behaviors and clinical decisions that together shrink the margin for error in patients who might otherwise traverse the path toward severe lung injury.

Enhancing Healthcare Team Outcomes

ARDS is a complex, multisystem syndrome whose management in the ICU demands synchronized action by an interprofessional team to prevent death,

shorten critical care exposure, and limit long-term disability. Intensive care physicians and pulmonologists coordinate ventilator strategies, proning protocols, and oxygen weaning, while also directing prevention of ventilator-associated pneumonia and venous thromboembolism in accordance with institutional bundles [24]. Respiratory therapists provide near-continuous ventilator oversight, facilitate secretion clearance, and guide transitions toward spontaneous breathing trials; nurses integrate these interventions at the bedside, monitor for early signs of deterioration, and serve as the primary conduit of education for patients and families. Pharmacists optimize antimicrobial therapy and anticoagulation, tailor diuretic regimens for conservative fluid management, and harmonize sedative–analgesic plans to promote early mobilization and minimize delirium. Dietitians construct individualized nutritional plans that support tissue repair and muscle reconstitution, while nephrologists manage renal replacement therapy when multiorgan dysfunction evolves. Physical and occupational therapists choreograph mobilization and functional retraining, and mental health professionals screen for and address anxiety, depression, and post-traumatic stress that are common after prolonged critical illness. Social workers, case managers, and chaplains address discharge barriers, spiritual care, caregiver support, and continuity with outpatient services. Evidence indicates that such integrated, team-based care improves outcomes by streamlining communication, ensuring adherence to protocols, and enabling timely escalation or de-escalation of therapies as the patient's trajectory evolves [25]. When systematically applied, this coordinated model translates pathophysiologic insight into practical, reproducible gains in survival, ventilator-free days, and quality of life, aligning individual clinician actions with shared goals that span the ICU, step-down units, and post-acute rehabilitation settings [25].

Outcomes

Despite meaningful advances in critical care, ARDS continues to confer substantial morbidity and mortality, with outcomes tightly linked to disease severity, age, comorbidity burden, and the timeliness of evidence-based interventions. Survivors often face a prolonged convalescence characterized by diminished exercise tolerance, dyspnea on exertion, and functional limitations that complicate return to work and daily activities. Many endure the sequelae of prolonged immobility and catabolic stress, including muscle wasting, critical illness myopathy, and neuropathy, alongside neurocognitive and psychological symptoms such as memory impairment, sleep disruption, and anxiety. These burdens underscore the importance of longitudinal follow-up in multidisciplinary clinics where pulmonary function can be monitored, oxygen needs reassessed, and rehabilitation strategies adjusted to evolving

capabilities. In the inpatient setting, earlier recognition of hypoxemia and prompt initiation of lung-protective ventilation are associated with better outcomes, while conservative fluid strategies after hemodynamic stabilization, timely prone positioning, and structured sedation practices help reduce complications. For patients with persistent gas-exchange failure, escalation to specialized centers capable of delivering venovenous extracorporeal support may salvage the most severe cases, though benefits depend on case selection and institutional experience rather than technology alone. Long-term quality of life remains variably reduced even when spirometric measures normalize, reflecting the primacy of muscular and neuropsychological recovery over purely pulmonary metrics. Consequently, outcome-focused care extends well beyond ICU discharge and emphasizes continuity: carefully planned transitions, caregiver education, and access to physical, occupational, and mental health services that sustain progress and prevent setbacks. While the condition itself cannot be absolutely prevented, vigilance for early hypoxemia, systematic application of protective strategies, and coordinated rehabilitation can meaningfully improve survival and shorten the path back to independence for many survivors [24][25].

Conclusion:

In conclusion, ARDS remains a formidable syndrome in critical care, but its prognosis has improved through the disciplined application of evidence-based, supportive management. The foundation of care is lung-protective mechanical ventilation, which is paramount for reducing ventilator-induced lung injury and mortality. This core strategy is effectively augmented by timely adjuncts such as prone positioning for severe hypoxemia and a conservative fluid management approach after initial resuscitation. While salvage therapies like ECMO offer a lifeline in refractory cases, their success is highly dependent on patient selection and center expertise. Crucially, the management of ARDS is not reliant on a single intervention but on a cohesive, interprofessional approach. The synergistic efforts of physicians, nurses, respiratory therapists, and pharmacists are essential to implement protocols, prevent complications, and guide patients through a prolonged recovery. Pharmacologic therapies, including corticosteroids, play a limited and carefully considered role. Ultimately, optimizing outcomes for patients with ARDS hinges on a standardized, multidisciplinary care bundle that prioritizes minimizing iatrogenic harm while supporting the body's innate healing processes over time.

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