

Acute Respiratory Distress Syndrome

Acute, diffuse inflammatory lung injury causing hypoxemia and bilateral infiltrates not fully explained by cardiac failure or fluid overload.

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Current through the ATS 2024 ARDS management update, ESICM 2023 ARDS guideline, SCCM 2026 neuromuscular-blockade guideline, and the 2024 Global Definition of ARDS. Low tidal-volume ventilation and prolonged prone positioning remain core therapy; corticosteroids, selected VV-ECMO, selected NMBA use and higher PEEP without prolonged recruitment maneuvers are guideline-supported with conditional patient selection.

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GUIDELINE

Educational content only. Use this handout for structured review; verify patient-specific decisions against local protocols and current guidelines.

Overview

A common final pathway for many different insults to the alveolar-capillary membrane.

ARDS is not a single disease but a shared endpoint: pneumonia, sepsis, aspiration, trauma, transfusion, and pancreatitis can all injure the alveolar-capillary membrane in the same way, producing acute hypoxemic respiratory failure with a common radiographic and physiologic picture regardless of what triggered it.

It is one of the more common reasons for mechanical ventilation in the ICU, and its severity - and the risk that goes with it - varies considerably from patient to patient. There is no single drug or procedure that reverses the underlying injury; management is almost entirely about protecting the lung from additional, iatrogenic injury while the triggering illness is treated, which is why the Management section below is the largest part of this topic.

Definition

The Berlin Definition frames ARDS by timing, imaging, the origin of edema, and oxygenation.

Medical visual available in the online topic: [ards-pathology-progression](#)

ARDS is defined by four elements that must all be present together, rather than by any single lab value: an acute timeline, characteristic imaging, exclusion of a purely cardiac cause, and a defined degree of hypoxemia measured under standardized ventilator conditions.

Timing	Onset within 1 week of a known clinical insult or new/worsening respiratory symptoms.
Imaging	Bilateral opacities on chest X-ray or CT, not fully explained by effusions, lobar collapse, or nodules.
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload; requires objective assessment (e.g. echocardiography) if no clear risk factor is present.

Oxygenation	Graded by PaO2/FiO2 ratio measured at PEEP >= 5 cmH2O (see Severity).
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ARDS is a clinical syndrome with many possible triggers - pneumonia, sepsis, aspiration, trauma, transfusion, and pancreatitis are among the most common - rather than a single disease with one cause.

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The table above is the 2012 Berlin Definition, which remains the framework nearly every major ARDS trial (ARMA through DEXA-ARDS) was designed and interpreted against. A 2024 Global Definition of ARDS built on Berlin rather than replacing its logic - see below for what it changes.

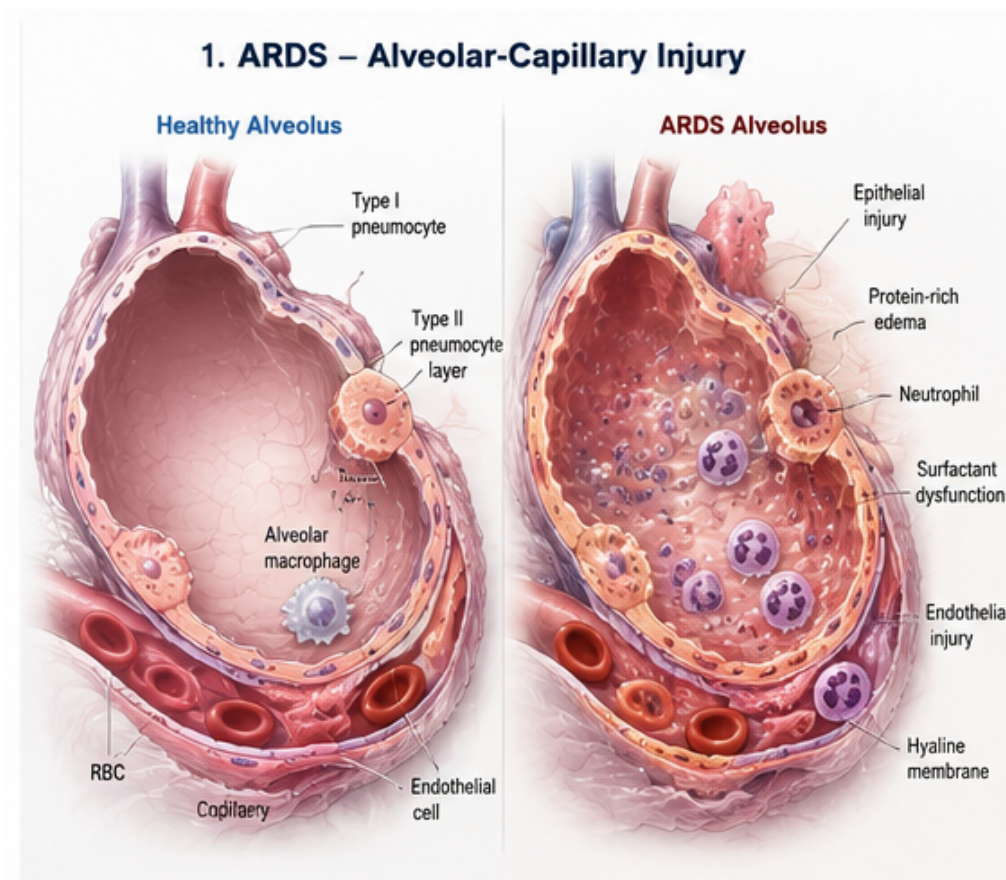
The 2024 Global Definition of ARDS extends the same four-element framework to patients who are not yet intubated and to settings without arterial blood gas or standardized ventilator access. It adds a non-intubated ARDS category (PaO2/FiO2 <= 300, or SpO2/FiO2 <= 315 when SpO2 <= 97%, on high-flow nasal oxygen >= 30 L/min or noninvasive ventilation/CPAP >= 5 cmH2O), permits SpO2/FiO2 as an alternative to PaO2/FiO2 throughout, and adds a resource-variable category for settings without reliable PEEP delivery or blood gas access (SpO2/FiO2 <= 315, with neither a minimum PEEP nor a flow-rate requirement). Bilateral opacities may be assessed by lung ultrasound as well as chest X-ray or CT under the 2024 definition.

ICU CAUTION

This content uses Berlin terminology and PaO2/FiO2 thresholds as the primary framework, since that is what the cited trials and the 2017/2023 ventilation guidelines were built around, and adds the 2024 Global Definition's SpO2/FiO2 and non-intubated criteria alongside it - the two are not in conflict, but a chart or trial that says "ARDS" without specifying which definition was applied should be read as Berlin unless stated otherwise.

Physiology

Diffuse alveolar damage produces shunt physiology and a heterogeneous, poorly compliant lung.



ards alveolar injury

The pathologic correlate of early ARDS is diffuse alveolar damage: capillary leak floods alveoli with protein-rich edema fluid, surfactant function is disrupted, and alveoli collapse or fill with exudate. The result is a lung that is not uniformly stiff but heterogeneous - some regions remain relatively normal while others are fully consolidated or collapsed, so a single tidal volume is distributed disproportionately into the smaller aerated portion of the lung (sometimes described as a functionally 'baby lung').

Two physiologic consequences follow directly. First, perfused-but-unventilated alveoli create intrapulmonary shunt, producing hypoxemia that resists supplemental oxygen and instead requires alveolar recruitment. Second, because the aerated lung volume is small, a tidal volume that seems modest relative to total body size can still overdistend the aerated regions, causing ventilator-induced lung injury - the physiologic rationale for low tidal volume ventilation.

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See the Physiology section for two standalone concepts this topic depends on: the Oxygen Delivery Equation and Ventilation-Perfusion Mismatch and Shunt.

Clinical Presentation

Acute dyspnea and hypoxemia in a patient with a recognized risk factor, evolving over hours to days.

- Acute onset of dyspnea and hypoxemia, typically within a week of a known risk factor (pneumonia, sepsis, aspiration, trauma, transfusion, pancreatitis).
- Tachypnea and increased work of breathing; findings can be subtle early and progress quickly.

- Diffuse crackles on auscultation, though the exam can be relatively unremarkable in early or mild disease.
- No single exam finding is specific to ARDS - the presentation overlaps substantially with its differential diagnoses (see below).

ICU CAUTION

The absence of volume-overload signs (jugular venous distension, peripheral edema, an S3) argues against a purely cardiogenic cause but does not exclude ARDS coexisting with a cardiac contribution - the two are not mutually exclusive.

Diagnosis

Diagnosis is clinical: apply the Berlin criteria and actively exclude a cardiac cause.

1. Confirm the timing criterion: new or worsening respiratory symptoms within 1 week of a recognized risk factor.
2. Review chest imaging for bilateral opacities not better explained by effusion, collapse, or nodules.
3. Actively assess for a cardiac cause - clinical exam, BNP/NT-proBNP, and echocardiography when there is no obvious risk factor for ARDS or when the picture is ambiguous.
4. Calculate the PaO₂/FiO₂ ratio at PEEP $\geq$ 5 cmH₂O to grade severity once the syndromic diagnosis is met.

ICU CAUTION

Volume overload and cardiogenic edema are the most common diagnostic pitfalls - they can produce bilateral opacities and hypoxemia that superficially mimic ARDS. Objective assessment of cardiac function is required whenever the cause is not obvious.

Severity

Berlin severity is graded by PaO₂/FiO₂ ratio at PEEP $\geq$ 5 cmH₂O, and should be reassessed after optimization.

Mild	PaO ₂ /FiO ₂ 200-300 (SpO ₂ /FiO ₂ 235-315 under the 2024 Global Definition)
Moderate	PaO ₂ /FiO ₂ 100-200 (SpO ₂ /FiO ₂ 148-235)
Severe	PaO ₂ /FiO ₂ $\leq$ 100 (SpO ₂ /FiO ₂ $\leq$ 148)

Severity is not fixed at diagnosis - a patient classified as moderate on presentation may reclassify as severe or mild after PEEP and FiO₂ are optimized over the first hours, and re-grading at that point is what should drive decisions like prone positioning.

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The management evidence below (low tidal volume, PEEP, prone positioning, neuromuscular blockade) was generated using Berlin/PaO₂-FiO₂-defined severity. SpO₂/FiO₂ bands from the 2024 Global Definition are a validated proxy, not a separately trial-tested severity scale - treat them as approximate when they diverge from a directly measured PaO₂/FiO₂.

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Interactive calculator available on the ICU Knowledge Map: pao2-fio2-ratio

Differential Diagnosis

Conditions that can mimic the Berlin criteria and should be considered before settling on ARDS.

- Cardiogenic pulmonary edema - the most common mimic; look for volume-overload signs and consider echocardiography or a BNP.
- Diffuse alveolar hemorrhage - consider with hemoptysis, a falling hematocrit, or a known bleeding diathesis or vasculitis.
- Acute eosinophilic pneumonia - a rapidly progressive presentation, sometimes with peripheral or bronchoalveolar-lavage eosinophilia.
- Acute interstitial pneumonia (Hamman-Rich syndrome) - a diffuse alveolar damage pattern without an identifiable ARDS risk factor.
- Drug-induced lung injury - review the medication list for known culprits.
- Transfusion-related acute lung injury (TRALI) - onset within hours of a blood product transfusion.

Management

Supportive care built around lung-protective ventilation, with escalation based on severity.

There is no therapy that reverses the underlying alveolar injury of ARDS; management is supportive, aimed at maintaining gas exchange while avoiding ventilator-induced lung injury until the lung recovers or the precipitating illness resolves. Treating the underlying cause (e.g. source control for sepsis) runs in parallel and is equally essential.

— Lung-Protective Ventilation

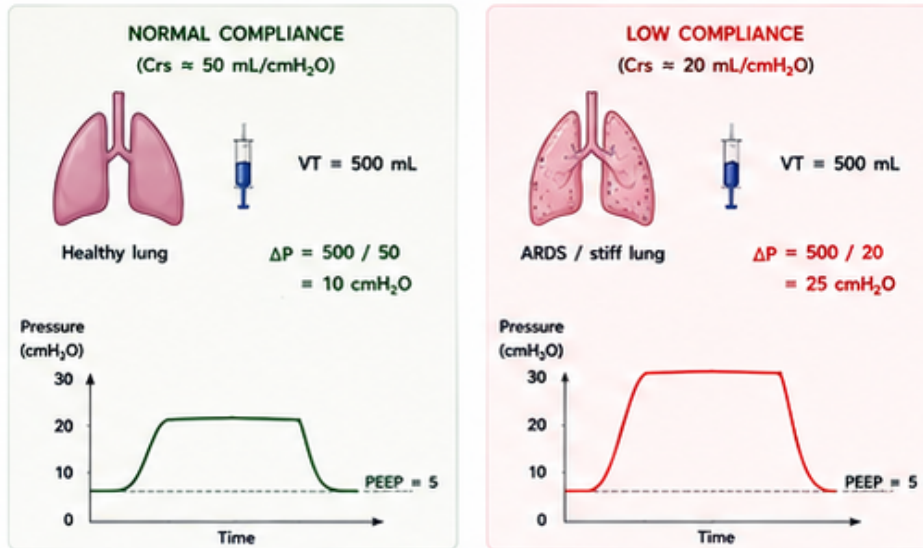
Low tidal volume with a plateau pressure ceiling is the foundational intervention in ARDS.

2. DRIVING PRESSURE – COMPLIANCE RELATIONSHIP

ΔP is determined by VT and respiratory system compliance (Crs)

RELATIONSHIP

$\Delta P = VT / Crs \rightarrow$ For a given VT, lower compliance = higher ΔP



KEY POINT

For the same tidal volume, lower compliance lungs require much higher driving pressure.

driving pressure compliance relationship

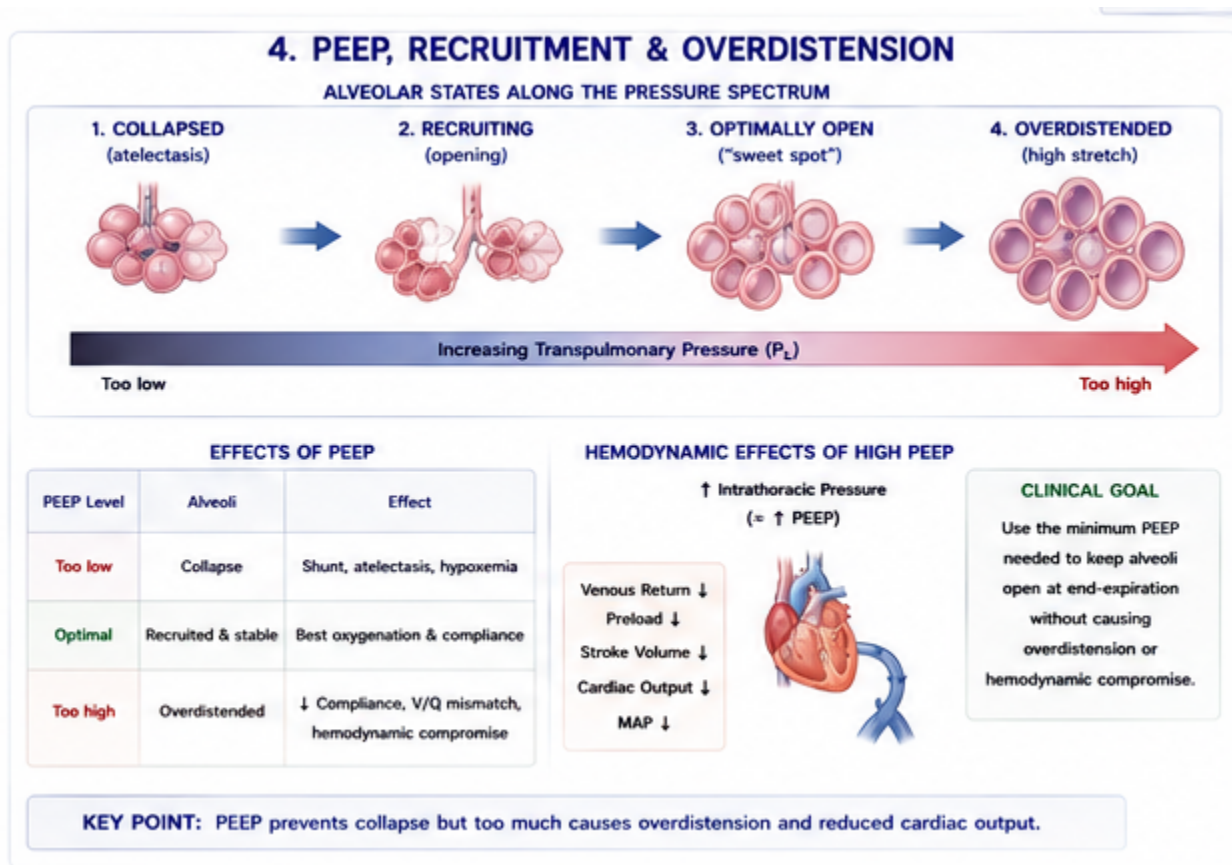
- Target tidal volume approximately 6 mL/kg predicted body weight (range 4-8 mL/kg).
- Keep plateau pressure ≤ 30 cmH₂O, reducing tidal volume further if needed to stay under this ceiling.
- Applies broadly across ARDS severity, not only to severe disease.

TRIAL

Grounded in the ARMA (ARDSNet) trial, which showed a mortality reduction with 6 mL/kg vs 12 mL/kg ventilation.

PEEP Titration

Higher PEEP without a recruitment maneuver is favored in moderate-to-severe ARDS; driving pressure helps judge whether it's helping or overdistending the lung.



peep recruitment overdistension

PEEP recruits collapsed alveoli and reduces shunt, but excessive PEEP can overdistend already-aerated regions and worsen driving pressure. Current guidance conditionally favors a higher-PEEP strategy without a formal recruitment maneuver over a lower-PEEP strategy in moderate-to-severe ARDS, titrated against oxygenation and mechanics rather than fixed at one number for every patient.

TRIAL

ALVEOLI found no difference in mortality or ventilator-free days between fixed higher- and lower-PEEP protocols in an unselected ALI/ARDS population - the guideline's preference for higher PEEP rests on later severity-stratified analyses, not on ALVEOLI's own null result.

ICU CAUTION

The 2023 ESICM guideline strongly recommends against prolonged, aggressive lung recruitment maneuvers in moderate-to-severe ARDS - see Landmark Trials for the ART trial, which found higher mortality with an aggressive recruitment-plus-titrated-PEEP protocol.

GUIDELINE

Interactive calculator available on the ICU Knowledge Map: driving-pressure

Fluid Management

After initial resuscitation, avoid unnecessary positive balance and transition toward conservative or active fluid removal when perfusion and congestion assessment support it.

- During active shock resuscitation, restoring perfusion takes priority; do not force a negative balance while the patient remains clearly preload responsive or under-resuscitated.
- After the acute resuscitation phase, stop fluids that no longer have an indication and use a conservative strategy; active diuresis or ultrafiltration should be guided by congestion, renal function, hemodynamics and tolerance rather than by a fixed net-balance target.
- Ongoing low-dose vasopressor use is not by itself a universal prohibition on deresuscitation, but it increases the need for repeated perfusion and fluid-responsiveness assessment.
- FACTT supports more ventilator-free days with a conservative strategy after shock stabilization; it did not demonstrate a mortality benefit.

TRIAL

FACTT demonstrated more ventilator-free days with conservative fluid management after stabilization, while contemporary sepsis guidance emphasizes individualized de-resuscitation rather than a mandatory timing or balance formula.

Prone Positioning

Use early prolonged prone positioning in appropriate moderate-to-severe ARDS, particularly when $\text{PaO}_2/\text{FiO}_2$ remains <150 despite an optimized lung-protective strategy.

- For intubated ARDS with $\text{PaO}_2/\text{FiO}_2 <150$ despite lung-protective ventilation and appropriate PEEP, prone positioning should be instituted early when no overriding safety issue exists.
- Use prolonged sessions, generally at least 16 consecutive hours, with a trained team and explicit airway/line rescue planning.
- Do not stop a safe prone session solely because oxygenation fails to improve immediately; the benefit is not limited to immediate oxygenation responders.

Indications

Severe, persistent hypoxemia despite an optimized lung-protective strategy.

$\text{PaO}_2/\text{FiO}_2$ below 150 that persists despite lung-protective ventilation, adequate PEEP, and a reasonable trial of optimization - this is the population in which the mortality benefit has actually been demonstrated, not a general therapy for any hypoxemic patient.

Patient Selection

Confirm the airway, lines, and hemodynamics can tolerate safe turning before proceeding.

Before turning, confirm the airway is secure, central and arterial lines are unlikely to dislodge, and the patient is hemodynamically stable enough to tolerate the maneuver. Obesity alone is not a contraindication but does require extra staff and appropriate equipment.

Duration

Sessions of at least 16 hours, reassessed daily against oxygenation once supine.

Each proning session should last at least 16 consecutive hours. Oxygenation is reassessed after a period back supine; proning is generally stopped once oxygenation is sustained ($\text{PaO}_2/\text{FiO}_2$ above roughly 150) supine with modest PEEP and FiO_2 across multiple attempts.

Contraindications

Separate true barriers to turning from relative hazards that can often be managed with specialist planning.

- Unstable spinal injury is a major contraindication unless a specialist team determines turning can be performed safely.
- Open abdomen, recent abdominal/thoracic surgery, elevated intracranial pressure, facial/airway surgery and major hemodynamic instability are not uniform absolute contraindications; weigh the specific anatomy, devices and physiologic risk with the relevant specialist team.
- Obesity and pregnancy are not automatic exclusions but require adequate staffing, positioning equipment and pressure-point/abdominal protection.

Complications

Mostly positioning-related, not a consequence of the physiology itself.

- Facial and airway edema.
- Pressure injuries at the face, chest, and knees.
- Transient desaturation or hemodynamic changes during the turn itself.
- Endotracheal tube or line displacement.

Neuromuscular Blockade

Selective rather than automatic: SCCM 2026 conditionally supports NMBA when $\text{PaO}_2/\text{FiO}_2 < 150$ and hypoxemia or ventilation targets remain unacceptable despite sedation.

Routine paralysis of every patient with moderate-to-severe ARDS is not supported. SCCM 2026 conditionally suggests an NMBA for adults with ARDS and $\text{PaO}_2/\text{FiO}_2 < 150$ who remain persistently hypoxemic and/or are not achieving mechanical-ventilation targets despite adequate analgesia and sedation. Patient-ventilator dyssynchrony, injurious respiratory effort and inability to deliver lung-protective ventilation are common practical reasons to use a short course.

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SCCM 2026: use NMBA selectively in $\text{PaO}_2/\text{FiO}_2 < 150$ with persistent hypoxemia and/or failure to achieve ventilation targets on sedation (conditional, low-certainty). Prone positioning alone does not mandate NMBA use.

CONTROVERSY

ACURASYS suggested benefit under deep-sedation-era care, whereas ROSE found no mortality benefit compared with a lighter-sedation strategy. The modern recommendation is conditional and phenotype/ventilation-target driven, not a universal ARDS bundle item.

Corticosteroids

ATS 2024 conditionally suggests corticosteroids for ARDS, but the optimal agent, dose, timing and duration remain uncertain.

- ATS 2024 conditionally suggests corticosteroids for adults with ARDS (moderate certainty of evidence).
- Do not convert that recommendation into one mandatory dexamethasone or methylprednisolone regimen: trials used heterogeneous drugs, doses, timing and durations, and the guideline did not establish a single preferred protocol.
- Consider infection, immunosuppression, neuromuscular weakness, hyperglycemia and the timing/etiology of ARDS when individualizing therapy.

TRIAL

DEXA-ARDS is an important positive trial in established moderate-to-severe non-COVID ARDS, but the ATS 2024 recommendation is based on the broader corticosteroid evidence base rather than on that trial alone.

Rescue Therapies

ATS 2024 conditionally supports VV-ECMO for selected severe ARDS after evidence-based conventional management has been optimized.

For selected patients with severe ARDS and refractory hypoxemia or injurious ventilatory requirements despite optimized lung-protective ventilation, PEEP and prone positioning, ATS 2024 conditionally suggests venovenous ECMO (low-certainty evidence). Selection should account for reversibility, duration of injurious ventilation, comorbidity, contraindications, center expertise and an explicit exit strategy; ECMO is not an automatic next step based on a single PaO₂/FiO₂ value.

Monitoring

What to trend day to day: ventilator mechanics, gas exchange, hemodynamics, and readiness to wean.

- Ventilator mechanics: plateau pressure, driving pressure, and compliance, trended over time rather than checked once.
- Gas exchange: arterial blood gases and PaO₂/FiO₂, reassessed after any change to PEEP or FiO₂.
- Hemodynamics: particularly important around proning and high-PEEP titration, both of which can affect venous return and right ventricular afterload.
- Sedation and analgesia depth, especially if neuromuscular blockade is in use.
- Daily assessment for readiness to reduce support once oxygenation and mechanics are improving.

ICU CAUTION

Specific monitoring targets and protocols vary by institution - confirm against local ICU protocol rather than treating the items above as fixed thresholds.

Complications

Both the disease and its treatment carry complication risk.

- Barotrauma, including pneumothorax, from high airway pressures or underlying lung fragility.
- Ventilator-associated pneumonia from prolonged intubation.
- ICU-acquired weakness, compounded by immobility, deep sedation, and neuromuscular blockade.
- Fibroproliferative changes in a subset of patients with prolonged ARDS, contributing to persistent restrictive physiology.
- Right ventricular strain from hypoxic vasoconstriction and elevated intrathoracic pressure at high PEEP.

Guidelines

Current guidance is anchored by ATS 2024 and ESICM 2023, with SCCM 2026 refining NMBA selection; earlier ATS/ESICM/SCCM recommendations remain relevant where retained.

ATS 2024 conditionally suggests corticosteroids, VV-ECMO in selected severe ARDS, neuromuscular blockade in selected early severe ARDS, and higher PEEP without prolonged recruitment maneuvers in

moderate-to-severe ARDS; it strongly recommends against prolonged recruitment maneuvers. SCCM 2026 further narrows NMBA selection to $\text{PaO}_2/\text{FiO}_2 < 150$ with persistent hypoxemia and/or inability to achieve ventilation targets despite sedation. Low tidal-volume ventilation with plateau pressure limitation and prolonged prone positioning remain core evidence-based therapy.

Landmark Trials

Nine trials that define current ARDS management, spanning ventilation, PEEP strategy, fluid management, positioning, sedation, steroids, and rescue therapy.

- ARMA (ARDSNet, 2000) - established low tidal volume ventilation.
- ALVEOLI (2004) - found no difference between fixed higher- and lower-PEEP protocols in an unselected population.
- FACTT (2006) - established conservative fluid management after shock resolution shortens ventilator time, without a mortality difference.
- ACURASYS (2010) - reported an adjusted mortality benefit with early neuromuscular blockade.
- PROSEVA (2013) - established early, prolonged prone positioning in severe ARDS.
- ART (2017) - found higher mortality with an aggressive lung recruitment and titrated-PEEP strategy compared with a conventional low-PEEP approach.
- EOLIA (2018) - tested early ECMO in very severe ARDS; primary endpoint not significant, interpretation complicated by crossover.
- ROSE (2019) - found no mortality benefit with routine early neuromuscular blockade, contradicting ACURASYS.
- DEXA-ARDS (2020) - a single-country trial reporting a large mortality benefit with early dexamethasone in moderate-to-severe ARDS, not yet confirmatory-trial-replicated.

Recent Evidence

Meta-analysis of neuromuscular blockade trials illustrates why pooling trials with different comparator strategies is difficult.

A pooled analysis of neuromuscular blockade trials in ARDS found no clear overall mortality benefit, with the estimate highly sensitive to the sedation strategy used in each trial's comparator arm - a reminder that meta-analysis cannot fully resolve a question when the underlying trials are not testing quite the same clinical strategy.

Controversies

The main controversies now concern whom to paralyze, which corticosteroid regimen to use, how to individualize PEEP and when to refer for ECMO.

CONTROVERSY

Neuromuscular blockade should no longer be framed as simply 'routine' versus 'never.' SCCM 2026 conditionally favors it in $\text{PaO}_2/\text{FiO}_2 < 150$ when hypoxemia persists or lung-protective ventilation targets cannot be achieved despite sedation, while acknowledging low-certainty evidence.

ATS 2024 also moved corticosteroids and selected VV-ECMO into conditional guideline-supported options, while leaving important implementation uncertainty: steroid regimen and timing, individualized PEEP/recruitability, and ECMO selection should be tailored rather than reduced to fixed formulas.

FOUNDATION SOURCES

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