

CALIFORNIA SOCIETY FOR RESPIRATORY CARE

The Hidden Burn

Practical Respiratory Management of Inhalation Injury

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Disclosures

Relevant Financial Disclosures

- Employed by University of California, Davis and Shriners Children's Northern California
- Receive Royalties as author of Surgical Nutrition topics for UpToDate
- Consultant for PolyNovo
- Contracted Research for SpectralMD
- Consultant for Avita Medical

None of these are relevant to this talk

Disclosures

Use of Artificial Intelligence

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OBJECTIVES

By the end of this hour, you will be able to

1

Recognize inhalation injury early and separate the findings that threaten the airway from the ones that do not.

2

Apply current evidence to ventilation, airway clearance and inhaled therapy at the bedside.

3

Anticipate the complications: carbon monoxide, cyanide, fibrin casts, pneumonia and ARDS, then plan the recovery.

Mr. R, 42, arrives from a house fire

Found by firefighters in a closed room. Coughing and hoarse, with soot around the nose and mouth.

Burns to the face and neck, about 18% TBSA. Drowsy, GCS 13.

What worries you most? What do you do in the next 10 minutes?

ON A 15 L/MIN NON-REBREATHER

SpO₂ 98%

RR 28 · HR 118 · BP 92/58

Lactate 9.2 mmol/L

Voice: hoarse, no stridor yet

WHY IT MATTERS

Inhalation injury changes the outcome of a burn

≈ 20 %

of hospitalized burn patients have an inhalation injury, and it is an independent predictor of death.

26 %

In-hospital mortality across the entire SI-ALI cohort

Rose to 50 % among patients with >20 % burn

+20 %

added expected mortality in major burns with inhalation injury alone and +60 % with pneumonia + inhalation injury

A skin burn can be excised and grafted. Injured airway cannot, so it is managed with supportive respiratory care.

Three injuries in one patient

Heat: upper airway

Thermal injury above the glottis. Edema can progress quickly and close the airway during the first hours.

Chemistry: lower airway

Soot and irritants inflame the trachea and bronchi, causing bronchorrhea, sloughing, casts, then ARDS.

Poisons: whole body

Carbon monoxide and hydrogen cyanide starve tissues of oxygen while the monitor can look normal.

No skin burn required. Inhalation injury occurs with and without cutaneous burns, and burns with inhalation injury develop ARDS earlier and more severely.

WHAT HAPPENS WHEN

The injury evolves for days after the fire

0–48 HOURS

Airway edema

Swelling builds, especially after fluid resuscitation. Loss of airway control is the early danger.

24–72 HOURS

Sloughing

Mucosa separates. Hypoxemia risk persists up to 72 hours with grade 2 or higher injury.

DAYS 3–7

Casts and infection

Fibrin casts, thick secretions, pneumonia and ARDS dominate the course.

WEEKS TO MONTHS

Recovery

Weak cough, reduced vital capacity and exercise limits can persist after discharge.

0 1

Recognize it

Red flags, the airway decision, and bronchoscopy

RECOGNIZE IT

Suspect it from the history, then the exam

History

Fire in an enclosed space
Prolonged exposure
Loss of consciousness
CPR at the scene
Others died in the same fire

Upper airway

Facial and neck burns
Singd facial or nasal hair
Oral or pharyngeal edema and blisters
Stridor

Lower airway

Cough, wheeze, hoarseness
Carbonaceous sputum
Increased secretions
Dyspnea, accessory muscle use
Altered consciousness

- **No single sign rules it in or out.**
- In one cohort, singd nasal hair and hoarseness did not predict early intubation.
- **Reassess often.**

THE AIRWAY DECISION

Intubate for a threatened airway, not for soot alone

Secure the airway when

Full-thickness central facial burns

Stridor or respiratory distress

Swelling seen on laryngoscopy, or upper airway trauma

Altered mentation, hypoxia or hypercarbia

Hemodynamic instability

Think twice about

Soot in the mouth or face and neck burns alone: in a 2019–2023 center review, neither predicted intubation beyond 24 hours.

Unnecessary intubation is common before arrival at burn centers.

But the airway can be lost within hours, and advanced burn life support advises securing it whenever patency is in doubt.

THE AIRWAY DECISION

Choose the tube you will need on day two

8.0 mm internal diameter, cuffed

If possible.

Use the largest tube possible

Why large: a smaller tube limits the bronchoscope channel for lavage and adds resistance on top of stiff, secretion-filled lungs.

Why it matters: 7.0 and 7.5 mm tubes often arrive from the scene, and upsizing means another airway intervention.

Tracheostomy: Timing depends on several factors. Early (within 7 days) often used with large burns. Repeated extubation and reintubation between operating-room trips is not ideal.

Cost of reintubation: each one raises laryngeal injury risk by roughly 1.5 times.

DIAGNOSIS

Bronchoscopy within 24 hours is the standard

IN- HOSPITAL SURVIVAL BY AIS GRADE

84%

grades 0–1

57%

grades 2–4

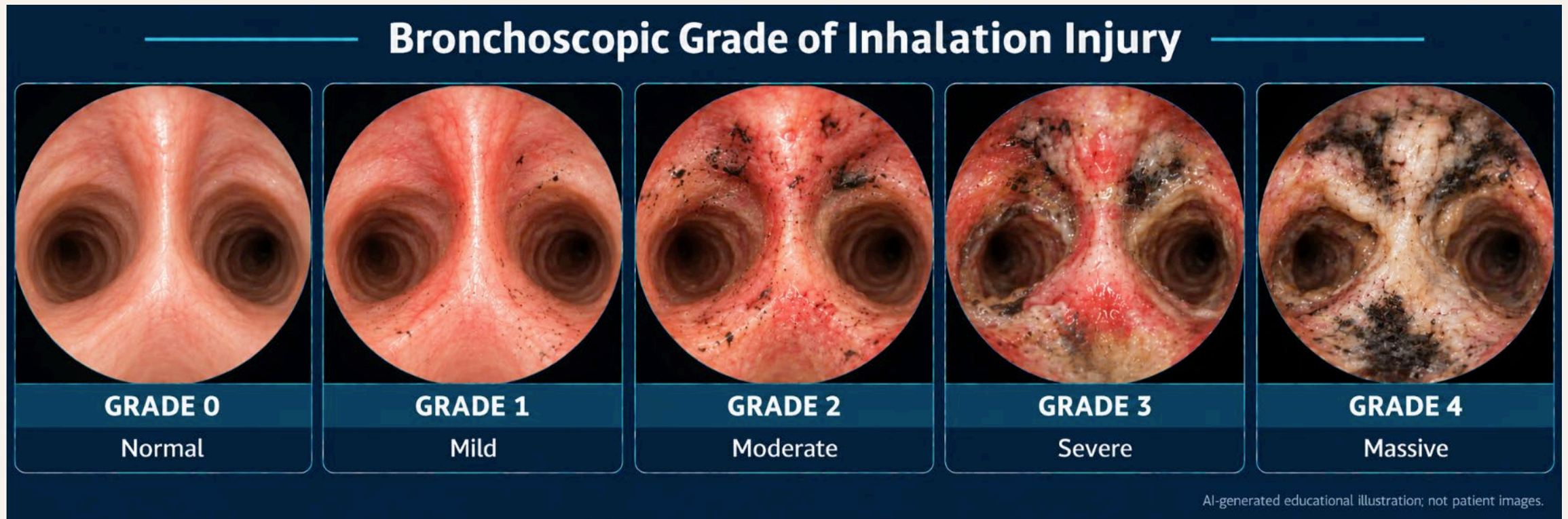
Confirms and grades the injury and guides therapy.

Consider sending a bronchoalveolar sample for culture

Repeat at 24–48 hours to lower false negatives, since injury evolves.

Limits: grading is subjective, and there is not consensus on its predictive value with respect to mortality

Grades of Inhalation Injury



GRADING

What the scope shows and what experts did about it

Grade	Bronchoscopic findings	Suggested Treatment
0 · none	No deposits, erythema, edema, bronchorrhea or obstruction	No inhalation-specific treatment
1 · mild	Patchy erythema, minor deposits	Standard care, Possible Initial Lavage
2 · moderate	Moderate erythema, deposits, secretions	Initial lavage, heparin, albuterol, NAC
3 · severe	Severe inflammation with mucosal sloughing, carbonaceous debris, and partial airway obstruction.	Initial and serial lavage, heparin, albuterol
4 · massive	Massive injury with mucosal necrosis, severe airway narrowing, and near-complete obstruction.	Initial and serial lavage, heparin, albuterol

Sources: Walker 2015 (Crit Care) AIS table; Milton-Jones 2023, Figs 3 and 7. Panel disagreement on mild-injury nebulized therapy.

02

The poisons

Carbon monoxide and cyanide: what the monitor misses

CARBON MONOXIDE

The pulse oximeter cannot see carbon monoxide

99%

SpO₂ can read this while
carboxyhemoglobin is near 40%.

Standard oximetry reads COHb as
oxyhemoglobin. PaO₂ is also normal, since it
measures dissolved oxygen.

Measure it: COHb by co-oximetry on an arterial or venous sample.

Treat first: give high-flow oxygen without waiting for a level.

A 15 L/min non-rebreather is not 100% FiO₂ (about 60%). Use a tight-fitting circuit, high-flow system or the ventilator.

CARBON MONOXIDE

Oxygen shortens it; hyperbaric oxygen is a judgment call

APPROXIMATE COHB HALF-LIFE



In Burns: Transfer out of a burn unit for hyperbaric treatment inappropriate.

CYANIDE

Suspect it, treat it, and warn the lab/nephrology

Suspect

Enclosed-space fire plus altered consciousness, seizure, unexplained cardiac dysfunction or arrest.

Lactate of 8 mmol/L or more is a trigger to treat.

A normal lactate argues against it.

Treat

Hydroxocobalamin, with high-flow oxygen.

Do not wait for lab confirmation when lactate is high.

Avoid reflexive sodium nitrite when CO is also present.

Watch

The deep red drug color can distort co-oximetry and colorimetric labs.

Draw COHb and labs first if possible.

Follow renal function: acute kidney injury and oxalate nephropathy have been reported.

03

Ventilate

Lung protection, the mode debate, rescue therapies and ECMO

Dialing in the ventilator: a starting point

Setting	Starting target	Burn-specific watch-out
Tidal volume	About 6 mL/kg PBW (6–8 acceptable)	Use height, never actual weight: edema changes weight daily
Pressures	Plateau under 30 ; driving pressure under 15 cmH ₂ O	A tight chest eschar raises pressures without lung disease
PEEP	At least 5; many units run 8 with inhalation injury	Avoid aggressive recruitment (ART trial); watch blood pressure
FiO ₂	100% until CO is excluded, then titrate down	Pulse oximetry misreads while COHb is high; use ABG and co-oximetry
Rate and pH	Set rate to pH; some hypercapnia is tolerable	CO ₂ production is high; a fixed low Vt can leave patients acidotic

Sources: Milton-Jones 2023; 2025 Chinese consensus; LAMiNAR 2021 (Burns Trauma); ARDSNet extrapolation. Starting points, not orders.

VENTILATION

Start with ARDS-style lung protection

6 ml/kg

predicted body weight

<30

cmH₂O plateau pressure, with or without ARDS

ΔP

Watch driving pressure and individualize PEEP

Honest caveat: ARDSNet excluded major burns, so this is extrapolated.

Still, Lung-protective ventilation is widely adopted with 74% of burn patients in an international cohort got low tidal volumes.,

Why burns complicate it: secretions and sloughed mucosa, resuscitation edema, and hypermetabolism that raises CO₂ production.

What burn ICUs actually do

LAMiNAR: 160 ventilated burn patients in 28 ICUs across 16 countries

74 %

got low tidal volume (8 mL/kg PBW or less). Median 7.3, with or without inhalation injury.

8 v 5

median PEEP, cmH₂O, with versus without inhalation injury. Peak pressure 31 versus 20.

16 v 21

ventilator-free days at day 28 with versus without inhalation injury (39% lower chance of liberation).

The catch: low versus high tidal volume was not associated with ventilator-free days (HR 0.99). The study was underpowered (160 of a planned 300), and the inhalation comparison was post hoc.

VENTILATION

The mode debate: no clear winner

Conventional, protective

Appropriate: the default

Pick the mode your team runs best and monitor pressures closely.

APRV

Appropriate with ARDS; uncertain without

First choice in the 2025 Chinese consensus, but no burn-specific trials.

HFOV

Rated inappropriate by the panel

No benefit in the OSCILLATE and OSCAR ARDS trials; less effective with coexisting inhalation injury.

HFPV

Rated inappropriate by the panel

An RCT matched low tidal volume; later retrospective data show no mortality gain and more kidney injury.

HFPV versus low tidal volume: Chung 2010

Single-center burn ICU, 62 adults with respiratory failure, 31 per arm. About 35–40% had inhalation injury; median burn size 34% TBSA.

12 v 11

ventilator-free days (HFPV v low Vt).
No significant difference.

Same

mortality and other secondary
outcomes. No clear winner.

29% v 6%

needed a rescue mode on low Vt
versus HFPV ($p=0.02$).

How to read it: HFPV did not beat protective ventilation on outcomes, but it more reliably met oxygenation and ventilation goals. It is a reasonable rescue option where the team is trained; it is not a default.

Limits: one center, unblinded by nature, modest size, and no inhalation-specific subgroup result. The expert panel still rated HFPV inappropriate.

When the pressures climb: a bedside differential

Peak up, plateau unchanged

An airway resistance problem: casts or mucus plugs, kinked or bitten tube, bronchospasm (including from NAC), or a **saturated expiratory filter**.

Peak and plateau both up

A compliance problem: lung or chest-walled edema, pneumonia, ARDS, pneumothorax, mainstem intubation, or a tightening chest eschar that needs surgical release.

Sudden desaturation

Think plugging first. A cast at the carina or in a main bronchus can mimic worsening ARDS. Suction, check the tube, and call for bronchoscopy.

Rising CO₂

Higher CO₂ production, dead space from obstruction, or auto-PEEP when bronchospasm and a high rate trap air. Check the flow waveform.

A documented event: in a nebulized-heparin trial, one patient had rising peak pressures and no measurable expired minute volume from probable filter saturation, and needed vasopressors for 20 minutes.

VENTILATION

Refractory hypoxemia: a stepwise ladder

- 1 Rule out plugging:** casts and secretions can mimic worsening ARDS. Suction, lavage, check the tube.
- 2 Consider prone positioning and neuromuscular blockade.**
- 3 Inhaled nitric oxide or prostacyclin:** appropriate for refractory hypoxemia.
- 4 Recruitment, gently:** aggressive recruitment with PEEP titration raised 28-day mortality in the ART trial (55% vs 49%) and can drop blood pressure.
- 5 Refer for VV-ECMO** before the patient is moribund, even if that means transfer.

VENTILATION

ECMO in burns: a salvage option with real trade-offs

49%

pooled hospital mortality in burn patients on ECMO

55%

pooled mortality when half or more participants had inhalation injury, versus 32% when under half did

65%

were weaned

TRADE-OFFS

Complications are more frequent than in other ICU patients (67.5% vs 40.2%), with bleeding risk around excision surgery.

CONSIDER WHEN

P/F under 80 after optimal management, or hypercapnia with pH under 7.25. Decide with a multidisciplinary team.

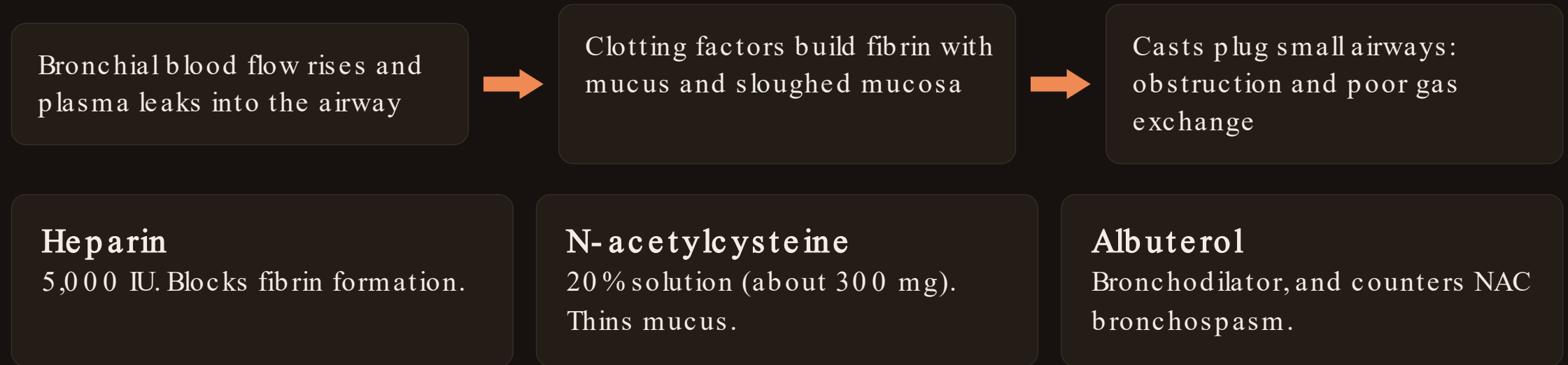
04

Clear the airway

Casts, nebulized therapy, bronchoscopy and chest physiotherapy

NEBULIZED THERAPY

The target is the fibrin cast



Typical regimen: every 4 hours for 5–7 days or until extubation, with coagulation and platelet monitoring. Protocols vary, so follow yours.

Why heparin? Strong biology, thinner human data

The target

Injured airways leak plasma. Clotting factors build fibrin casts that plug small airways. Heparin blocks fibrin formation where it starts.

Beyond clotting

Preclinical work suggests anti-inflammatory effects too. A meta-analysis of animal smoke-inhalation studies reported a protective effect of nebulized heparin.

Why nebulize

Delivery to the airway aims to concentrate drug locally. Systemic effects are uncommon but not zero: one trial patient had an aPTT above 150 seconds.

The evidence ladder so far: animal studies, then retrospective human series, then a few small randomized trials, then pooled analyses. The top rung is still thin.

Studies that favored heparin

Study	Design	Regimen	Result
McGinn 20 19	Retrospective, n=48	Heparin + NAC + albuterol	Ventilator days 3.0 v 6.5; ICU days 5.5 v 13
HHI study 20 18	Matched retrospective, 36 v 36	10,000 units every 4 h for 7 days, alternating with albuterol and NAC or bicarbonate	Ventilator-free days 21v 13.5 (p=0.031). Mortality 2.8% in both. Major bleeding 5.6% v 11.1%, not significant
Hakim 2024 (QJM)	Randomized, n=88	Nebulized heparin	Higher P/F ratio; no change in severe ARDS, failed weaning or mortality

Caution: HHI's primary outcome reached significance only after excluding patients who died or left on the ventilator

Studies that found no benefit, or problems

Study	Design	Regimen	Result
Glas 2020 (Dutch-Belgian)	Double-blind RCT, stopped early; 13 randomized	25,000 IU every 4 h for up to 14 days v saline	No efficacy analysis. 30 % of heparin doses withheld v 15% (bleeding concern). Two serious ventilatory events
White 2025 (abstract)	12-year retrospective, n=162	Single-center protocol	No difference in ventilator-free days, mortality or pneumonia. Bleeding 68% v 55% (p=0.081)
Risinger 2025 (Am Surg)	Retrospective, grade II–III injury, 40 patients	Heparin + NAC + albuterol protocol (47.5% received it)	Ventilator days 5 v 6 (p=0.76); survival 57.9% v 52.4% (p=0.73)

Reading across both slides: retrospective studies cut both ways, and the only blinded trial was too small to answer the question.

HEPARIN · POOLED EVIDENCE

The 2025 meta-analysis: promising, but pooled from weak parts

7 studies (3 randomized, 4 cohort), 950 patients, searched 2014–2024

0.79

Mortality, risk ratio (0.64–0.97)

–0.50

Ventilation duration, SMD (–0.85 to –0.15)

0.35

Ventilator-free days, SMD (–0.05 to 0.75): not significant

0.95

Pneumonia, RR (0.80–1.13): no effect

1.15

Major bleeding, RR (0.88–1.50): not significant

Why caution: heterogeneity of 45–60% on the main outcomes, mixed designs, and the authors themselves call for large randomized trials.

HEPARIN · DOSE AND SAFETY

No standard dose, and a real safety job for RTs

5,000

units every 4 h for 5–7 days, with NAC
(2025 Chinese consensus)

10,000

units every 4 h for 7 days, alternating with
albuterol and NAC (HHI)

25,000

units every 4 h for up to 14 days (Dutch-
Belgian RCT)

What went wrong in trials

Blood-stained sputum and bleeding worry caused heparin doses to be withheld; one patient's aPTT exceeded 150 s; a saturated expiratory filter caused a pressure emergency.

RT checklist

Expiratory filter and humidifier set-up per protocol. Trend peak pressures after each treatment. Report blood in sputum. Know who holds doses and checks aPTT and platelets.

Sources: 2025 Chinese consensus; HHI 2018; Glas 2020. Doses differ by protocol; follow your pharmacy and burn-service guideline. The checklist is a practice summary.

NEBULIZED THERAPY

Delivering the cocktail: the RT's real job

42

treatments in a 7-day, every-4-hour course, plus the albuterol that goes with each

Filters and circuits: NAC and heparin can clog expiratory filters and sensors. Check resistance often and change per your protocol; Vanderbilt suggests at least every shift.

Bronchospasm: NAC can provoke it. Give albuterol with or before it and watch peak pressures.

Safety labs: know who is tracking coagulation and platelets, and hold the dose if bleeding appears.

Feasibility: a Dutch-Belgian trial stopped early partly because the schedule was hard to deliver.

BRONCHOSCOPIC CLEARANCE

Therapeutic bronchoscopy: who benefits?

Injury severity	Initial lavage	Serial lavage
Mild	Inappropriate	Inappropriate
Moderate	Appropriate	Uncertain
Severe	Appropriate	Appropriate

National Burn Repository (over 9,000 patients):
therapeutic bronchoscopy plus pneumonia was linked
to 18% lower mortality. Observational.

Prophylactic sequential bronchoscopy trial (Carr 2013):
no significant differences in outcomes.

RT role: set up suction and saline, raise FiO₂ and watch pressures during the procedure, manage the airway and sedation interface, and record what was found.

Chest physiotherapy and mobilization

The evidence

Kubo 2021: 47 patients, chest PT twice a day for 20–40 minutes, with less pneumonia.

Small, single-center and not randomized in the way larger trials are, so treat it as supportive.

At the bedside

Positioning, manual techniques and suction, adapted to burns over the chest.

Vests are often unsuitable with chest burns or on ventilated patients.

Use closed-circuit suction and follow the VAP bundle.

Mobilize early with the team as soon as it is safe.

No prophylactic antibiotics. Prevent pneumonia with clearance, hygiene and early liberation, not with empiric drugs.

WHAT NOT TO DO BY REFLEX

Not routine for inhalation injury

Systemic steroids

Rated inappropriate by expert panels

Prophylactic antibiotics

Rated inappropriate. Treat proven infection.

Nebulized sodium bicarbonate

Uncertain, with no supporting literature.

Racemic epinephrine and HFOV

Limited or no support as routine measures. Use for a specific problem, not as a default.

0 5

Liberate and recover

Extubation decisions and the long road after discharge

LIBERATION

Extubation: thin evidence, high stakes

What the guidance says

Consensus statements give no validated criteria for extubating inhalation injury.

Reintubation is hard in a swollen airway, and each additional intubation raises laryngeal injury risk by roughly 15 times.

Practice points

Check cuff leak, secretion burden and cough strength.

Confirm P/F, mental status and hemodynamics.

Avoid extubating around OR trips; plan it between them.

Have the difficult-airway kit and best operator ready.

The recovery is long, and it is respiratory

What persists

At 3 months: lower FEV₁/FVC, peak cough flow, respiratory muscle strength and FVC.

Restrictive patterns and low DLCO in some survivors.

Lower employment at 24 months.

Results vary: an older cohort had normal PFTs.

What helps

A 120-patient randomized trial tested 12 weeks of pulmonary rehabilitation.

The consensus strongly recommends early rehab (80.65% voted "recommend").

Arrange PFT follow-up before discharge.

After CO poisoning, screen cognition 4–6 weeks out.

BACK TO MR. R

What we do for Mr. R

- 1 SpO₂ 98% is unreliable. Run **co-oximetry** and give 100% oxygen.
- 2 Lactate 9.2, altered mentation, enclosed fire: **hydroxocobalamin**. Draw labs first and tell the lab.
- 3 Hoarse, burned face and neck: **secure the airway early**, largest tube possible, most experienced operator.
- 4 **Lung-protective ventilation**: Vt about 6 mL/kg PBW and plateau pressure under 30.
- 5 Bronchoscopy within 24 hours with **AIS grade**, then the nebulized regimen per protocol.
- 6 Call the **burn center** early.

Mr. R is a fictional composite case.

The first hour and first 24 hours

First hour

100% oxygen by non-rebreather

Co-oximetry: COHb and MetHb

Look for red flags: hoarseness, stridor, edema

Draw cyanide labs before hydroxocobalamin

Intubate early

First 24 hours

Vt about 6 mL/kg PBW, Pplat under 30

Bronchoscopy and AIS grade

Start the nebulized regimen per protocol

Closed-circuit suction, secure the tube

Repeat COHb until normal

Days 2–7, liberation and follow-up

Days 2–7

Deliver every nebulized dose on time

Check filters and circuits each shift

Chest PT and mobilization

Rising pressures or falling P/F: think plugging first

Escalate stepwise; know the ECMO pathway

Liberation and beyond

Cuff leak, secretions, P/F, mentation

Do not time extubation around OR trips

Post-extubation airway watch

Arrange PFTs and pulmonary rehab

Cognitive screening after CO exposure

TAKE HOME

Five things to remember

- 1 The airway is a moving target. Soot alone is not an indication; swelling is.
- 2 SpO₂ lies in smoke. Co-oximetry, 100% oxygen, and think cyanide.
- 3 Lung protection first. No mode has beaten it in burns.
- 4 Clear the casts. Bronchoscopy, nebulized therapy, chest PT, and run the protocol well.
- 5 Plan the recovery. Early rehab and pulmonary function follow-up.

OPEN QUESTIONS

What we still do not know

How accurate and reproducible is bronchoscopic grading?

Does lavage help, and at which severity?

Does nebulized therapy change outcomes, and for whom?

What is the best ventilation strategy?

Can AI grade bronchoscopy images?

Can biomarkers predict who will deteriorate?

Who should get ECMO, and when?

Registries and multicenter trials to answer all of the above

THE HIDDEN BURN

Questions?

California Society for Respiratory Care · October 8, 2026

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